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CDC 40450

# PRECISION IMAGERY AND AUDIOVISUAL MEDIA MAINTENANCE SPECIALIST

(AFSC 40450)

Volume 2

*General Subjects and Maintenance Procedures*

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# Preface

THIS SECOND volume of CDC 40450, *Precision Imagery and Audiovisual Media Maintenance Specialist*, is a refresher course in general subjects and maintenance procedures. Chapter 1 is a review of general shop practices. Chapter 2 reviews methods for corrosion prevention and procedures for preparing equipment for storage, shipment, and climatic conditions. Chapter 3 covers the principles of photography. Chapter 4 covers hand tools, power tools, and measuring devices. Chapter 5 reviews soldering techniques.

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## CHAPTER 1

# General Shop Practices

WHEN MAINTAINING precision imagery and audiovisual media equipment, you must determine the repair procedures for restoring components to an operational status. Although mechanical restoration is usually difficult, electronic restoration is far more complex. Repairing electronic equipment requires the maximum good workmanship. If you do not use good practices in maintaining the complex components of today's photographic and audiovisual equipment, you create problems that did not exist. Thus, you not only have the original problem but you also have the additional problem (or problems) which you created, such as:

- Short circuits, overheating, damaged parts, and power losses.
- Broken leads, connections, and pins.
- Heat-damaged insulation, solid-state devices, and printed circuit boards.
- Deterioration of signal quality, wiring, and inclosures.
- High maintenance costs.
- Deterioration of test equipment and repair equipment.

It is thus very important that we discuss good general maintenance practices. In this volume we stress techniques and precautions.

## 1-1. Equipment Repair Practices

Many technical manuals contain instructions relevant to maintaining electro-optical sensor systems. Specific instructions for certain repair and maintenance (and certain test procedures) are not always included. In this case, you must first determine the repair procedures to correct the defective items. This requires you to interpret policies, consider possible procedures, and then devise the correct procedure.

If electronic equipment with sufficient replacement parts were always used under ideal climatic conditions, you would have little difficulty in performing maintenance. This is not always possible. You must temporarily substitute equivalent parts, reducing the time the equipment is out of service. However, don't substitute parts in circuits that are critical to sustaining the reliability standards of the equipment.

In performing precision imagery and audiovisual media maintenance, you must use the standard maintenance practices that are equal to, or exceed, those standards set forth in the applicable technical manuals. Pay particular attention to good workmanship, proper use of tools, and maintenance of clean, well-organized work areas.

**200. Associate general maintenance practices with their description.**

**General Repair of Equipment**. When you do not have a direct replacement for defective nonelectronic parts, such as brackets, bushings, casings, or cabinets, you must fabricate them in accordance with the authorization for local manufacture. In fabricating parts, keep the materials, dimensions, and tolerances as close to those of the original parts as possible. The fabricated part must be similar to the original part in composition, weight, and durability. This assures that the operation and performance are not adversely affected by the interchange.

**Bonding.** While working in your AFSC, you may encounter two types of bonding—thermal and mechanical. Thermal bonding is the joining of two pieces of metal by welding, brazing, or soldering. However, if the necessary welding or brazing cannot be done with a small propane torch, route the component to the proper repair shop. In light brazing, take care to form a smooth and uniform joint that is free of cracks, blisters, and excess pores. Solder electrical connections so that the soldered joint makes a smooth concave fillet between the wire and the terminal. Smoothly blend the edges of the solder into the metal surfaces.

With mechanical bonding, you join two units with pins, rivets, or threaded fasteners. Insert and tighten the various pins, rivets, or threaded fasteners with enough force to join the two parts. Do not use so much force that the parts or the fasteners become damaged. If a torque wrench is available, use it to tighten threaded fasteners to the specified torque.

**Insulating.** Electronic circuits used in precision imagery and audiovisual systems may present serious problems. Insulate all exposed electrical connections and terminals from (or have sufficient clearance from) conducting materials, or you will have short circuits. Insulate all electrical connections and terminals from an equipment casing (or cover) that might be shifted (or dented) during normal equipment usage so that it cannot contact an exposed electrical connection. Allow at least a 0.05 inch clearance between mounting hardware, other electrical connections, and equipment casings and coverings.

**Repair and Refinishing.** When minor dents or bends occur in equipment casings, repair (or remove) the dent or bend, using a backup tool and a mallet or special metal-working hammer. Clean, treat, and refinish the repaired areas in accordance with directions given by the manufacturer or in technical manuals. When specific directions are not available, clean, treat, and refinish the repaired area in accordance with local repair procedures.

**Cleaning.** During periodic maintenance, and before repair, clean photographic equipment in accordance with the procedures in technical manuals or other directives. If a technical manual (or directive) is not available for an item, develop a set of procedures that are applicable for the existing conditions. In developing cleaning instructions, remember that the best procedure is to consider the type of the equipment and the nature and amount of contamination.

In any maintenance activity, the amount of repair work required often depends on how equipment is handled and stored. To prevent damage to equipment during handling and storage, place electronic assemblies in containers (or in a common container with a suitable barrier material between assemblies).

**Handling.** Unnecessary damage often occurs to electronic assemblies due to rough handling. Use extra care when removing an assembly from, or inserting it into, a subsystem. If it is a plug-in, board-type assembly, be sure that the guide pins are properly aligned before pressing the assembly into place. If the board tilts during insertion, do not continue to press. Instead, straighten the assembly, and then apply even pressure to avoid tilting. If you force any tilted or cocked electronic assembly into position, you may bend or break the connecting terminals.

Removing an assembly is just as important as inserting it. Pull the assembly straight out to remove it from the major component. Never cock, twist, pry, or carelessly jerk an electronic assembly while removing it from the mounting or connectors. CAUTION: Do not touch or press against leads and pins when handling an electronic assembly that has been removed from its chassis. Perspiration on connectors causes corrosion. Due to miniaturization of parts, the leads, connectors, and pins have been stiffened; thus, they are brittle and break easily if bent or subjected to force. If a lead or pin is accidentally bent, do not try to straighten it unless straightening is absolutely necessary.

Be careful when using tools around any electronic assembly. Always make sure the tool does not press against leads, pins, or other parts that can be easily bent. Such pressure may destroy a good part.

**Abrasives.** Abrasive tools and materials are used primarily for grinding, cleaning, and polishing the surfaces of tools and equipment. These tools and materials vary according to the type of work to be done and the manner in which they are to be used. Some of the more common abrasives you will probably use are explained in the following paragraphs.

***Whetstones.*** A whetstone is usually a small rectangular solid abrasive material such as emery or stone, which is used to sharpen tools by hand-rubbing the tool on the surface of the whetstone. Knives are usually sharpened this way because the temper of the knife is easily removed when sharpened by a grinder.

***Sandpaper.*** Sandpaper is a heavy, tough paper that has sand glued on one side. It is graded according to the coarseness of the sand. It is primarily used on wood, but fine sandpaper (number 000) may be used for dressing down a slightly pitted commutator of an electric motor. It is also used to clean enamel from the ends of enameled wires when preparing them for soldering.

***Emery cloth.*** Emery cloth consists of powdered emery glued to cloth. It is used on metals in the same manner as sandpaper is used on wood. It should never be used on commutators of electric motors or generators. Emery cloth is graded according to its coarseness.

***Crocus cloth.*** Crocus cloth is made by gluing iron oxide to cloth. It is used to polish metal surfaces.

***Steel wool.*** Steel wool consists of a tangled mass of steel wire. It is graded according to coarseness, and is used for removing rust and paint and for cleaning and polishing metals. Never use steel wool on electronic equipment if there is a possibility of its small wires entering the chassis. This may cause electrical shorts when power is applied.

***Wire brushes.*** Wire brushes are provided in many sizes and shapes. They are used for removing rust and corrosion and for cleaning material surfaces. Be careful when handling a wire brush since the metal bristles are very sharp and could injure the user.

Be careful in selecting an abrasive for a job. Your equipment can be damaged by the improper use of abrasive agents or abrasive tools. If you are not sure what to use, STOP—consult the appropriate directive.

**Exercises (200):**

1. Match the term in column B with its description in column A. Terms in column B may be used once or more than once.

*Column A*

____ (1) Allow at least 0.05 inch clearance between mounting hardware.
____ (2) Clean and treat the area in accordance with local procedures.
____ (3) Unnecessary damage occurs to electronic assemblies.
____ (4) Keep materials, dimensions, and tolerances close to those of the original parts.
____ (5) Use extra care when removing an assembly from a subsystem.
____ (6) Materials used primarily for grinding, cleaning, and polishing.
____ (7) Thermal and mechanical.
____ (8) Consider the nature of the equipment and the amount of contamination.
____ (9) Join two units with pins, rivets, or threaded fasteners.
____ (10) Sandpaper, emery cloth, steel wool.
____ (11) The operation and performance of a part are not affected by this interchange.

*Column B*

a. Fabrication of nonelectric parts.
b. Bonding.
c. Insulating.
d. Repair and refinishing.
e. Cleaning.
f. Handling.
g. Abrasives.

*Column A*

____ (12) Use a backup tool and mallet.

## 1-2. Common Maintenance Hardware

In the repair of electronic equipment, you are sometimes required to fabricate minor mechanical parts. Although you are concerned primarily with the repair of electronic circuits, a knowledge of mechanical fasteners is necessary.

### 201. Associate hardware used during maintenance with its uses.

**Mechanical Fasteners.** Several kinds of mechanical fasteners are used to mount on a chassis. Some of the mechanical fasteners used are:

(1) Pins—used to connect one mechanical part to another. These pins may be called dowel, taper, shear, clevis, drive, or spring.

(2) Rivets—used in electronic equipment to fasten braces and mounting parts.

(3) Studs—inserted in a chassis to hold mechanical parts (grooved for retaining ring) or to provide electrical terminal connections.

(4) Retaining rings—used to hold a part on a stud or shaft or to retain a part within a housing device.

(5) Threaded fasteners—used to hold component parts in place or to fasten one component to another.

***Pins.*** Dowel and taper pins are made to precise dimensions and require a close-tolerance hole. The application of a taper pin is shown in figure 1-1,A. The application of a dowel pin in a blind hole is shown in figure 1-1,B. Both of these are classed as "snug fit" pins. Insert them in line with the hole to prevent binding. Use a soft metal-face mallet or an arbor-type press to drive them into the receiving hole.

The drive pins and spring pins, shown in figure 1-2, require holes having a diameter slightly less than their diameter. Drive pins are made with equally spaced splines around the pin shank. When the pin is driven into a hole, the splines develop pressure against the walls of the hole, holding the drive pin in place. The spring pin is also compressed when driven into a hole. This puts pressure against the walls of the hole and keeps the spring pin in place. Both drive and spring pins are classed as "tight fit" pins. Discard all used drive pins and damaged spring pins; however, you may reuse undamaged spring pins.

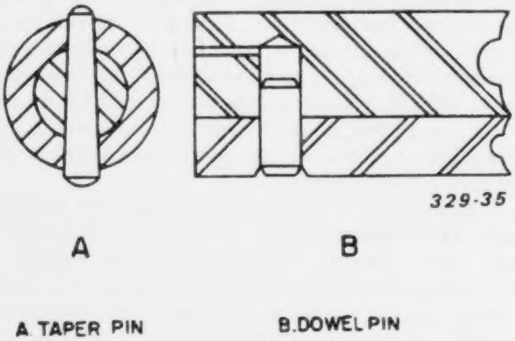

Figure 1–1. Dowel and taper pins.

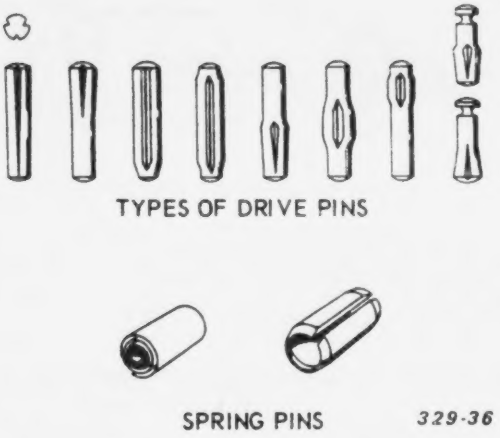

Figure 1–2. Drive and spring pins.

The clevis pin, figure 1-3, is somewhat different from other pins since it is a "loose fit" pin. This pin has a head at one end and is held in place by a retainer at the other end. The retainer normally is a cotter pin. After inserting the cotter pin, wrap it around the clevis pin shank. Make sure that the cotter pin does not protrude so that it won't catch on clothing or cause injury.

***Rivets.*** In electronic equipment, flush- and raised-head rivets are generally used for fastening braces and mounting parts. Flush-head rivets require countersunk or skin-dimpled holes to receive the tapered rivet head. As shown in figure 1-4, skin-dimpling is an indentation around the edge of a hole.

Before setting a rivet on electronic equipment, remove all shock-sensitive components. If design permits, use a hand-operated rivet squeezer to set the rivets. You may also use a bucking bar of sufficient mass to assure complete setting and expansion of the rivet. For raised-head rivets, the bucking bar has a recess of appropriate size and shape to accommodate the head of the rivet. This allows the transferring of the compressive forces to the rivet shank rather than to the rivet head. Make certain that the correct size and shape of recess is used (fig. 1-5). Be sure the

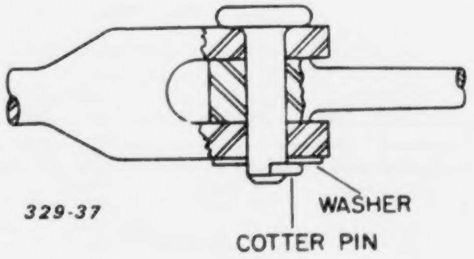

Figure 1–3. Clevis pin.

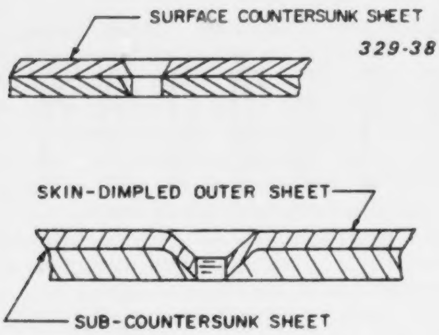

Figure 1–4. Countersunk and skin dimpled rivet holes.

bucking bar does not touch the parts being joined. Never permit the bucking bar to rock or bounce during a rivet setting operation.

When riveting two component parts together, correctly set and align the rivets. Examples of proper and improper riveting are shown in figure 1-6. Improper riveting does not conform to the specifications set forth for both flush- and raised-head rivet connections. Criteria for a proper riveting operation are:

*a*. Riveted parts do not move.

*b*. The diameter of the upset (flattened end of the rivet) is approximately 1½ times the diameter of the rivet shank.

*c*. Flush-head rivets do not protrude more than 0.01 of an inch above the flush surface.

*d*. The gap under the head of raised-head rivets is less than 0.004 of an inch.

*e*. The gap between the tapered side of a flush-head rivet and the countersink is less than 0.002 of an inch.

***Studs*.** Some typical studs and terminals are shown in figure 1-7. As illustrated, such studs are generally cylindrical. However, the end of the stud is shaped according to its application. Typical shapes are: grooved for a retaining ring, split for a terminal connection, and hollowed and tapped for accepting a screw. The shank end of the stud is smaller in diameter than the stud end and may be either solid like a rivet or tubular like an eyelet.

***Retaining rings*.** A retaining ring is used to hold a part on a stud or shaft. It can also be used to retain a part within a housing device. Retaining rings come in different shapes and sizes but are generally classed as snap rings, spiral rings, or "truarc" rings, all of which are shown in figure 1-8. The "truarc" ring may be expanded. When installing retaining rings, you must:

(1) Remove all burrs and sharp edges on the shaft or stud.

(2) Press snap rings (by hand) onto the receiving groove of the shaft or stud.

(3) Expand the spiral ring by hand, place it over the shaft or stud, slide it down the shaft, and then release it when it is positioned in the groove.

(4) Expand or compress a "truarc" ring only with the special pliers that are designed to fit into the slots, or holes, in the ring. Then install the ring onto the receiving stud or into the housing. Do not overexpand the smaller, external-type "truarc" retainers.

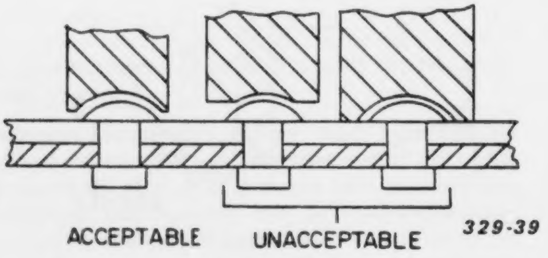

Figure 1–5. Bucking bar recess.

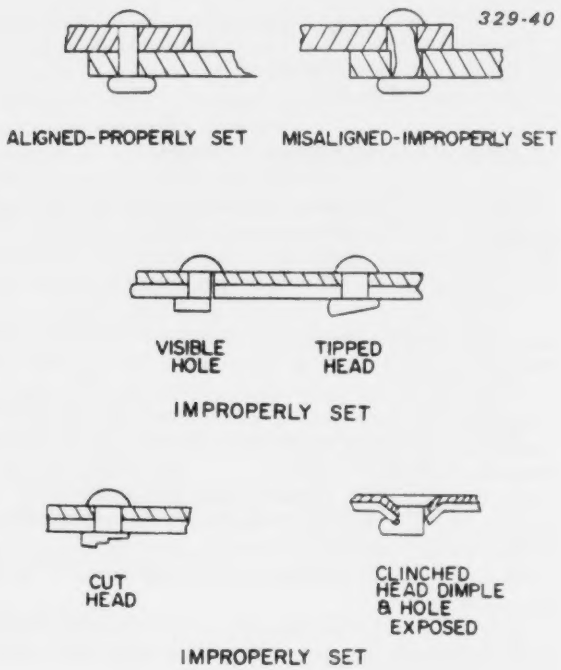

Figure 1–6. Proper and improper riveting.

***Threaded fasteners*.** Threaded fasteners (screws, nuts, and bolts) are frequently used to hold or fasten components. They normally have coarse threads and are usually made of steel or other hard materials. Sometimes the nuts are fixed in place or are attached to one of the two members before assembly. If this type of attached nut floats in a retaining house, alignment is not as important or difficult. However, if the nut is welded or riveted in place on one of the assemblies, you must ensure precise alignment in mating the parts before tightening.

A *locking nut* is used with some threaded fasteners to make them vibration-proof. You can divide locking nuts into two general classifications—self-locking and externally locked. One type of self-locking nut contains a captive nylon or similar material washer. This washer has an inside diameter slightly smaller than the threaded portion of the locking nut. When the nut is turned onto a threaded fastener, the washer compresses. Pressure is exerted on the threaded fastener. This creates friction which prevents the locking nut from vibrating loose. Self-locking nuts may be reused if the threaded fastener cannot be turned past the locking device when finger pressure is applied.

A *castellated nut* is another type of locking nut. It is notched at the top to accept a cotter pin. Insert the cotter pin through the notches in the nut and the hole in the mating threaded fastener. Then wrap the cotter pin around the nut so that it does not protrude. This keeps the nut from vibrating loose. Regular nuts can be made into locking nuts by drilling a hole through the mated nut and bolt. After drilling the hole, use safety wire to secure the nut.

The *setscrew* is another threaded fastener normally used to hold parts on shafts. If the shaft has a flat side, only one setscrew is required to secure the part. However, two setscrews, separate 90 to 120°, are required to hold a part on a round shaft.

***Washers.*** You may be required to use washers when installing threaded fasteners. There are two basic types of washers—flat washers and lock washers. Flat washers are used to distribute the pressure of a tightened screw, nut, or bolt and to protect the edge of the hole that receives the screw or bolt. They are also used to space or to position parts. Lock washers are used to prevent nuts or bolts from loosening due to vibration.

CAUTION. Since a regular lock washer under compression can damage plastic or other soft materials, it is seldom used in contact with plastic or very soft metals unless it is specifically called for.

As the nut or threaded fastener compresses the lock washer, the projections on the washer grip both the surface of the nut and the surface of the component. Some typical lock washers are shown in figure 1-9. Always use the recommended type of lock washer when working on equipment.

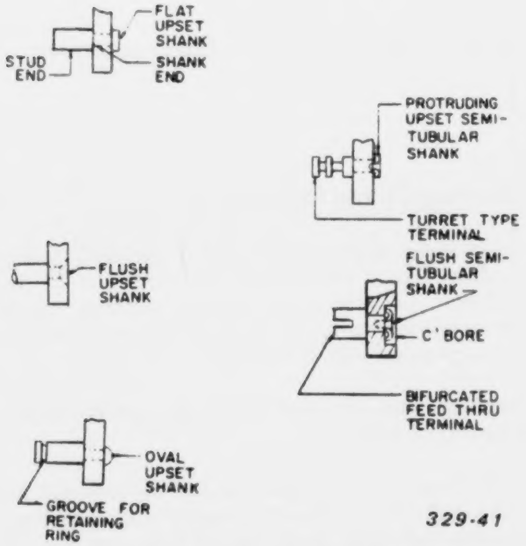

Figure 1-7. Typical studs and terminals.

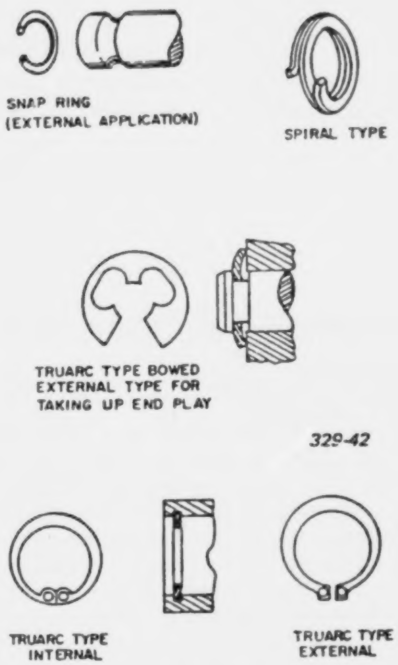
SNAP RING (EXTERNAL APPLICATION)
SPIRAL TYPE
TRUARC TYPE BOWED EXTERNAL TYPE FOR TAKING UP END PLAY
329-42
TRUARC TYPE INTERNAL
TRUARC TYPE EXTERNAL

Figure 1-8. Typical retaining rings.

**Exercises (201):**

1. Match the term in column B with its description or use in column A. Items in column B may be used once or more than once.

| *Column A* | *Column B* |
|---|---|
| ____ (1) Require a clost tolerance hole. | a. Pins. |
| ____ (2) Used to hold components. | b. Rivets. |
| ____ (3) Used for fastening braces and mounting parts. | c. Studs. |
| ____ (4) May either be solid of tubular. | d. Retaining rings. |
| ____ (5) Used to distribute the pressure of a tightened screw or bolt. | e. Threaded fasteners. |
| ____ (6) Dowel, taper, and clevis are examples of these. | f. Washers. |
| ____ (7) Used to hold a part on a shaft. | |
| ____ (8) Screws, nuts, and bolts. | |
| ____ (9) May be flushed- or raised-head. | |
| ____ (10) Used to prevent nuts or bolts from loosening. | |

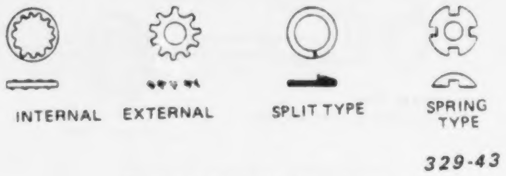

Figure 1-9. Typical lock washers.

## 1-3. Electrostatic Discharge (ESD) Precautions

The reliability and operational effectiveness of Air Force systems are the concern of all Air Force personnel, uniformed members, and civilian work force. Damage to electrical and electronic parts from ESD has long been known. The current trends in technology are toward greater complexity, increased density, and hence thinner dielectrics between active elements, resulting in electronic devices becoming even more sensitive to ESD. Various electronic parts are more electrostatic discharge sensitive (ESDS) than others. These can be damaged by ESD levels commonly generated by personnel testing, handling, repairing, and assembling electronic components without their being aware that a discharge of static electricity has even occurred. Many ESDS electronic devices such as semiconductors, thick and thin film resistors, chips and hybrid devices, and piezoelectric crystals can be damaged or destroyed by ESD levels of a few hundred volts, far below our threshold of awareness (around 4,000 volts). We cannot see, feel, or hear discharges below that level.

**202. Cite sources of static electricity, failures that can occur, and precautions to take against electrostatic discharge (ESD).**

Typical prime charge sources or generators commonly encountered are listed in table 1-1. These are prime generators of static electricity, which are nonconductors, and are typically made of synthetic materials. Electrostatic voltage levels generated with these insulators can be very high since they are not readily distributed over the entire surface of the substance. The conductivity of some insulative materials is increased by the absorption of moisture under high humidity conditions, which tends to dissipate static charges. Table 1-2 shows typical electrostatic voltage levels generated by personnel in a maintenance facility.

Numerous parts are susceptible to damage when an ESD occurs across their terminals or leads or when these parts are exposed to electrostatic fields. ESDS parts installed in assemblies such as a printed circuit board can be damaged by an ESD. Some common parts that are suseptible to ESD are:

- Microelectric devices such as metal semiconductor field effect transistors (MOSFETs), programmable read-only memory (PROMs), read-only memory (ROMs), random-access memory (RAMs), and complementary metal oxide semiconductors (CMOS).
- Discrete semiconductors.
- Film resistors.
- Resistor chips.
- Other thick and thin film devices.
- Piezoelectric crystals.

Failures that ESD cause can hurt the reliability of your sensor systems. ESD can cause total failure of electronic parts, intermittent failures, or erroneous signals. Also, latent or delayed failures can be caused by ESD. Items that have been partially damaged by ESD may check out electrically on the repair bench, but can fail on equipment in operation when subjected to the stresses of wide temperature ranges and mechanical shock.

Whenever an item is handled outside of its ESD protective packaging or by disassembly from the shielding of the outside case of an electronic assembly, it must be in a protected area. A protected area generally consists of a grounded work bench, a personnel wrist strap, a grounded floor mat, and grounded tools and equipment all connected to a common ground. The elimination of static generators is also a requirement for an ESD protected area. The level of protection is dependent upon the level of sensitivity of the ESDS items being worked.

**Exercises (202):**

1. Sealed concrete, vinyl, and plastic bags are examples of what?

2. Name three common parts that are susceptible to ESD.

3. When can items fail after being partially damaged by ESD.

4. Name five items that are in an ESD protected area.

## 1-4. Cleaning Optical Surfaces

In order to take sharp pictures, the camera needs to have clean optics. As a maintenance technician, it is your responsibility to ensure the optical surfaces of the equipment that you have worked on are cleaned before you place the equipment back in service.

**203. State the materials and cite the procedures used to clean optical surfaces.**

As you know, there are many optical surfaces that you must maintain as a precision imagery and audiovisual maintenance specialist. Each has its own materials and procedures to use when cleaning them. We will discuss the

## TABLE 1-1
### TYPICAL SOURCES OF STATIC ELECTRICITY

| Object or Process | Material or Activity |
|---|---|
| Work Surfaces | Waxed, painted or varnished surfaces<br>Common vinyl or plastics |
| Floors | Sealed concrete<br>Waxed, finished wood<br>Common vinyl tile or sheeting |
| Clothes | Common clean room smocks<br>Common synthetic personnel garments<br>Nonconductive shoes<br>Virgin cotton (Note) |
| Chairs | Finished wood<br>Vinyl<br>Fiberglass |
| Packaging and Handling | Common plastic bags, wraps, envelopes<br>Common bubble pack, foam<br>Common plastic trays, plastic tote boxes, vials, parts bins |
| Assembly, Cleaning, Test and Repair Areas | Spray cleaners<br>Common plastic solder suckers<br>Solder irons with ungrounded tips<br>Solvent brushes (synthetic bristles)<br>Cleaning or drying by fluid or evaporation<br>Temperature chambers<br>Cyrogenic sprays<br>Heat guns and blowers<br>Sand blasting<br>Electrostatic copiers |

NOTE: Virgin cotton can be a static source at low relative humidities such as below 30 percent.

## TABLE 1–2
### TYPICAL ELECTROSTATIC VOLTAGES

| Means of static generation | Electrostatic voltages | |
|---|---|---|
| | 10 to 20 percent relative humidity | 65 to 90 percent relative humidity |
| Walking across carpet | 35,000 | 1,500 |
| Walking over vinyl floor | 12,000 | 250 |
| Worker at bench | 6,000 | 100 |
| Vinyl envelopes for work instructions | 7,000 | 600 |
| Common poly bag picked up from bench | 20,000 | 1,200 |
| Work chair padded with polyurethane | 18,000 | 1,500 |

materials and procedures used for cleaning camera lenses because these are the most critical optics in your job.

The materials you need when cleaning camera lenses are:

*a*. Hand syringe.
*b*. Camel's hair brush.
*c*. Lens tissue or cotton.
*d*. Alcohol.

First, you blow any coarse dust particles from the surface of the lens with a hand syringe. Then you use the camel's hair brush to remove smaller particles of dust from the lens. *When using this brush, never run it across the surface of your skin because you will contaminate it with your natural body oils.*

To clean smudges, oily film, or fingerprints wipe the lens gently with lens tissue or cotton dampened with alcohol. You should avoid excessive rubbing and move the swab in one direction and change it often. This will prevent you from scratching the lens. You then dry the lens with the same material but without the alcohol.

When using alcohol, you must have adequate ventilation. Do not keep your hands in contact with alcohol for any length of time. Never use it near a flame, spark, or other source of ignition and never try to drink it.

Before cleaning any optical surface make sure you check the equipment's technical manual for special instructions or procedures.

**Exercises (203):**

1. What are the four materials you need to clean a camera lens?

2. Cite the procedures for cleaning camera lenses.

CHAPTER 2

# Corrosion Control and Equipment Preparation for Storage, Shipment, and Climatic Conditions

DETERIORATION of equipment results from exposure to hostile environments or conditions. We devote a major portion of this chapter to corrosion—its cause, control, prevention—and your corrective actions. This special treatment of equipment is a very important part of your job. We also discuss why you must protect precision photographic equipment exposed to conditions where it may deteriortate rapidly in arctic, desert, and tropical climates.

## 2-1. Corrosion Control

Corrosion can be defined as the deterioration of a metal by its reaction to its environment. Corrosion of the materials in a photo system component may cause a failure due to component weakening, intolerable change in size, or roughening of a critical mating surface. When the corrosion is concealed, it may continue undetected until the defect is so pronounced that total failure occurs. Particular care is always exercised when systems are designed and when parts are assembled to eliminate blind spots which might hide an unfavorable condition. However, equipment designed so that plug-in units can be easily replaced may have hidden areas where undetected corrosion can develop. Give special attention to these areas during an inspection or when removing, restoring, or replacing such units.

Corrosion may cause a piece of equipment to fail. For example, a switch or relay exposed to adverse conditions may be affected in two ways. First, severe corrosion of the springs or operating parts may prevent the contacts from opening or closing. Second, corrosion of the two contacting surfaces may produce such a high resistance at the point of contact that there is not enough current to operate the circuit, even though the contacts are closed. All items of electrical equipment that produce movement or act as a result of movement may be affected in a similar manner.

Various kinds of plant growth, generally classified as fungi, may attack lens elements, metal surfaces, and even the insulation or wiring. The by-products of some types of fungus can act as an electrolyte, causing insulation breakdown. This could cause serious problems. For example, a failure of this kind at some point in a wiring harness may cause either crossed (loosely coupled) or short circuits. A crossed circuit may result in a current being transferred from some live circuit into a circuit which, according to switch positions, should not be energized. If a live circuit should be accidentally crossed with a circuit that should not be energized, the result could be extensive damage to the system and to people in an area around it.

### 204. Identify the causes of corrosion.

**Causes of Corrosion.** Among the various causes of corrosion, the most common are moisture, oxygen, and bacteria, or fungus growths. The effects of oxygen are rapid, especially if there are also favorable conditions of moisture and temperature. At normal temperatures and with a dry atmosphere, corrosion may occur so slowly that it takes considerable time for the action to affect the efficiency of the system. When sufficient moisture and heat are present, however, the oxidation of steel, magnesium, aluminum, and similar metals can proceed far too rapidly.

***Forms of microorganisms.*** Live spores of microorganisms are present in the air unless the air has been sterilized. In almost any sample of air there are various spores that become active and prosper under the proper conditions. (As an example of how numerous these forms of life are, scientists believe there are over 100,000 different kinds of fungi in the temperate regions of the world.) Those organisms that require oxygen are referred to as aerobic, while those varieties that prosper in the absence of oxygen are referred to as anaerobic. Anaerobic bacteria occur most plentifully where oxygen is not readily available. Strange as it may seem, however, both varieties of organisms (aerobic and anaerobic) may exist side by side in a given environment.

Anaerobic bacteria also thrive under conditions where there is a presence of sulfates. Microorganism activity of this kind is usually indicated by a black coating over a thin layer of white material. The black coating is usually a sulfur compound, such as ferrous sulfide. While sulfur would not normally be found in an ultra-high-altitude environment, it is a common contamination of the low-altitude environment surrounding certain factory or industrial areas.

***Differential environment.*** If the environment is not uniform, there are conditions similar to those of stress corrosion. As a basic example of what we mean by differences of environment, consider a long cable buried in the earth. Part of the cable is in clay and another part is in sandy soil. Due to the different environments, there is an effect of producing a cell similar to a storage battery. The internal movement of electrons from one area to another results in corrosion. The rate of corrosion is determined by the size of the areas involved and the potential differences of the cell. A variation of the water content of the environment of one section compared to that of another also sets up similar conditions. A variation in the concentration of salts in each environment is another example of a differential environment.

***Moisture*.** Equipment that is located outdoors is exposed to moisture either as rain, snow, or condensation. But even equipment that is protected from the weather or located inside an aircraft is still subject to condensation. Compartments that are not airtight draw in or expel air with changes in temperature and pressure. For example, during flight, the inside of the vehicle gets warm and/or the outside pressure decreases and the air expands inside the compartment. This drives out part of the air. As the inside temperature falls or the outside pressure increases, air from the outside comes into the compartment. Since air in a vehicle on the flight line is normally drawn in during the cool night periods when moisture in the air is greatest, there is frequently an accumulation of condensation inside the compartments. The addition of a small amount of moisture each day raises the humidity of the air inside the compartment so that eventually the dewpoint is reached. This is the point when condensation forms a film of moisture in the compartment and on its contents.

Units normally sealed from the outside air are particularly vulnerable when the seal leaks or breaks because the passageway for the air is usually very small. A sealed compartment with a small break actually accumulates moisture faster than one with a break large enough to allow free air circulation and ventilation. Equipment operated in a controlled environment, where there is a constant temperature and pressure, does not collect moisture, even though the equipment is not completely sealed. But the same piece of equipment removed to an uncontrolled environment may accumulate moisture rapidly. Serious problems such as the corrosion caused by the moisture, the associated fungus growths, etc., may cause severe changes in the electrical characteristics of the equipment.

**Exercises (204):**

1. What type of microorganism can cause corrosion in an area where oxygen is not readily available?

2. What are the most common causes of corrosion?

3. What is the most probable contributor of corrosion inside an unpressurized camera compartment?

4. Why is a sealed container with a small break more susceptible to corrosion than one with a large break?

**205. Given the results of corrosion or circumstances under which it would occur, specify each instance of corrosion by its name.**

**Types of Corrosion.** Good corrosion control goes hand in hand with good maintenance. Most metals are subject to corrosion under certain conditions. The direct cause of corrosion may be classed as chemical (acid) and electrical (galvanic action). The cause may also be a combination of both. In the construction of precision photographic equipment, materials are chosen to avoid corrosion. However, special considerations, such as strength, weight, expansion, and/or contraction (due to temperature variation), may sometimes require the use of metals that are not ideal for corrosion resistance. At a junction of two dissimilar metals, a special joint or transition material may be required to act as a barrier (corrosion insulator). This is one of the reasons you must follow certain special procedures in applicable technical orders when making repairs or replacements on photographic equipment.

***Stress corrosion*.** Stress corrosion is often found in those areas of equipment where the metal has been shaped by hammering, forging, or stretching. It is the result of a residual stress which has not been relieved after working the metal. Studies show that dissimilar stress conditions in the same metal cause galvanic corrosion. Various methods are used to relieve the stress in metal after it is worked, but the treatment is not always successful. Affected areas are usually noted at bends, but they may occur in relatively flat areas that have been formed by swaging, forging, hammering, or similar processes.

***Fretting corrosion*.** How or why fretting corrosion occurs is not clearly understood. It occurs when closely fitted metal parts are subjected to vibration. A common example is the corrosion that occurs at a pressed fit—such as at a spot where a bearing is pressed onto a shaft. A tight fit made by the shrinking process is also subject to this type of corrosion. When fretting corrosion takes place, the contracting surfaces develop areas in which there is pitting. Damage to steel parts is shown by powdery deposits (usually red) at the mating surfaces.

***Intergranular corrosion*.** This type of corrosion is found at the grain boundaries of a metal. It is apparently caused by minor differences in composition within the same piece of metal. Possibly, the effect is the result of internal strains or adjustments. Corrosion of this type is usually indicated by irregular cracks that follow the grain boundaries.

***Pitting corrosion*.** Pitting is probably the most common type of corrosion. It is indicated by pits in a metal surface—spots where the metal has actually been removed. Pitting is most severe when it is caused by a galvanic cell in which the anode is concentrated in a relatively small area. When first affected by pitting corrosion, magnesium and aluminum alloys have a white or gray powderlike dust on their surface. Even in the early stages, if you inspect the surface of the metal under adequate magnification, you find tiny pits after the powder is cleaned away.

***Uniform etch corrosion*.** Most attacks by chemicals, such as acids, produce an effect on a polished surface which is first noticeable as a general dulling of the polish. When this condition is allowed to continue, the surface gradually becomes rough and a definite pattern appears. When you examine the corroded areas closely, you see that the etched areas have a uniform depth.

***Exfoliation corrosion.*** This is a type of granular corrosion characterized by elevation of the surface grains of the metal. The area may have the appearance of very small eruptions. This is caused by corrosion by-products forming at the grain boundary just below the surface. These by-products exert sufficient pressure on the bottom side of the surface grains to force them outward. This type of corrosion appears most often on pieces of metal formed by the extrusion process.

***Fatigue corrosion.*** This is a special type of corrosion where the combined effects of repeated stress and corrosion cause metal fatigue. Metal loses its resistance to stress more rapidly when exposed to a corrosive environment. Damage from fatigue corrosion is greater than the sum of the damage from both the cyclic stress and the corrosion. During the first stage, the combined action of the corrosion and the cyclic stress causes pitting of the metal and crack formation. In the second stage, metal fatigue failure proceeds by extension of the crack. Ultimate failure of the metal occurs under cyclic stress, even though the corrosive environment is removed; however, fracture of a metal part from fatigue corrosion generally occurs at a point far below the normal fatigue limit, even though the amount of corrosion is very small. Corrosion protection of all parts subject to cyclic stresss is very important. Consider those environments that are only slightly corrosive as possibly presenting a serious hazard.

**Exercises (205):**

1. What type of corrosion would turn a polished surface dull?

2. What type of corrosion is characterized by elevation of the surface grains of the metal?

3. If you were to find white or gray powdery deposits that blotch the surface, what type of corrosion would be present?

4. What type of corrosion is caused partly by cyclic stress?

5. Attack on the grain boundaries of material is caused by what type of corrosion?

### 206. Cite the methods of preventing corrosion.

**Prevention of Corrosion.** Choosing the correct materials to replace defective parts is one of the best means to prevent corrosion. Improper selection of materials may create a corrosion situation that cannot be controlled. The next preventive measure is the control of environmental conditions. Despite these precautions, some corrosion always takes place, and you must make periodic inspections to detect this corrosion and correct it before it causes a mission failure.

Galvanic corrosion often results when two different metals are placed in contact with each other. Many corrosion problems result from immediate contact of dissimilar metals. Some examples of such corrosion-creating practices are:

*a.* Carbon steel, brass, or aluminum fittings used to attach two pieces of stainless steel.

*b.* Carbon steel supports used to hold stainless steel or copper lines.

*c.* Carbon steel grounding clips attached to stainless steel or copper lines.

*d.* Carbon steel bolts used in stainless steel fittings.

*e.* Cadmium-plated steel fittings screwed into (or onto) stainless steel objects.

*f.* Stainless steel wire filters mounted in aluminum frames.

*g.* Fittings with a stainless steel, copper, and cadmium plating in direct contact with each other.

Since stainless steel is normally considered to be relatively immune to corrosion, the foregoing examples should emphasize the problems caused by joining dissimilar metals. Where you must use unlike metals, you must follow special installation procedures to minimize the effects of galvanic corrosion. Follow these special procedures in the case of all repairs and all replacements. Watch for conditions that might cause corrosion.

***Environmental control.*** There are four methods you may use to control the environment around selected equipment. Study these in the following listing:

*a.* Use heating and/or cooling equipment to hold the temperature to a small variation so that moisture is not drawn into component enclosures, boxes, or compartments.

*b.* Use dehumidifiers to keep the moisture content of the air so low that corrosion is minimized.

*c.* Use filters to purify the air and reduce the problems caused by dust.

*d.* Use electronic sterilization to free the air of live spores that produce fungus growths.

Since control of the environment may not always be practical, you must consider other means that are available to ensure proper functioning of equipment.

***Treatment of equipment.*** There are several ways of keeping equipment free from corrosion. In the case of small boxes, such as the kind that contain a switch, it might be most practical to completely seal the unit. (This is often done at the factory with inexpensive disposable equipment, which is normally not repaired.) Larger items, such as junction boxes, are usually made so that seals may be replaced when necessary. In addition to being sealed, certain equipment is pressurized with dry air or dry nitrogen. Certain very critical pieces of equipment are mounted in canisters that are purged of all moisture and air before being pressurized with dry nitrogen or dry helium. Equipment or wiring may be sprayed or painted with special materials to make them resistant to fungus. Most fungus-control agents have toxic properties. These toxic properties, so unfavorable for the growth of fungus, may also poison you. Take special precautions to keep from getting poisoned. Follow directions for ventilation, clothing, masks, and other protective equipment when using such toxic materials.

**Exercises (206):**

1. Is the choice of materials critical if corrosion is to be prevented?

2. Can environmental conditions be controlled as a means of preventing corrosion?

3. List at least five things that should be avoided in order to prevent galvanic corrosion.

4. List three different procedures that might be used as a means of treating equipment to prevent corrosion.

5. List four methods of controlling the environment as a means of preventing corrosion.

**207. Cite the main steps in correcting a corrosive condition.**

**Corrective Measures.** Many corrective measures have been implied or touched upon in our discussion of the causes of corrosion. However, for purposes of clarity and completeness, we list those measures with which you must be familiar. Situations caused by faulty materials or faulty repair procedures are practically unlimited, so we discuss them only in the most general terms. In most cases, it is not sufficient merely to remove the effects of corrosion; you must also eliminate or at least minimize the causes.

Corrective action concerning corroded equipment or components is either repair or replacement. The nature of the item and the extent of the corrosion determines which course you follow. To repair an item, clean it to remove the corrosion. Then restore it to a serviceable condition. Even when an item is replaced, you may have to do considerable cleaning in the area adjacent to that from which the equipment was removed.

A replacement item sometimes leads to corrosion due to the wrong choice of material (such as using carbon steel washers when another material was intended). In a case such as this, carefully research and determine the correct item by using the technical order that applies to the equipment. When the recommended materials do not give satisfactory service, report the condition through proper channels as soon as possible. Follow up on the problem until it is solved.

Treatment of metals for the various types of corrosion varies from one metal (or alloy) to another. You can expect to find many approved treatments. Specific explanations of these treatments are given in detail in TO 1-1-2, *Corrosion Control and Treatment for Aerospace Equipment.*

Actual recording of field experience with corrosion in photo systems would fill a large book, but some recurring reports are worth your consideration. One of these sounds overly simple, since the corrosion occurs from a simple "leak" test of pressurized equipment using a soap solution. The corrosion is caused by using soaps other than those specified for leak-test solutions. Certain soaps have a strong attraction to moisture and are able to draw moisture from the air. This results in a damp area on the metals which, when surrounded by a dry area, produces a galvanic cell. This results in rapid destruction of the anode area.

The photo shop and work area often reveal a strange assortment of foreign materials when they are carefully inspected by maintenance personnel. Dirt, machine screws, washers, lens caps, short stubs of wire, and strips of insulation are just a few examples of the materials that have been found. Besides being detrimental to the photo products, the accidental deposit of such foreign materials into the equipment may set the stage for corrosion to develop in unexpected places. Even though the corroded areas have been detected and repaired, don't neglect them in future inspections. Once a surface has been affected, it remains a vulnerable spot until the affected item is replaced.

**Inspection.** To the average person, housekeeping activities within the shop and work area may seem so simple that we should not consider them in this discussion.

However, some individuals are so careless (or so lazy) that they would sooner sweep dirt "under the rug" than dispose of it properly. When you are in charge of an inspection or a repair job, be alert to see that housekeeping in the shop and work area is complete. On a "cleanup" job, give particular attention to those areas that are hidden from visual inspection. Check these hidden areas by feeling for signs of dirt, moisture, or other liquids. In areas too small to admit your hand, you can make a fairly good check by means of a light and a small inspection mirror. You should never assume that a job has been finished correctly just because visual checks make it appear that way. Always make a detailed check and be sure your equipment is ready to perform in a first-class manner.

You must find corrosion before you can correct it. For this reason, inspect the components of the system as frequently as possible and as thoroughly as practicable. It is not always possible to thoroughly inspect the system daily on the work site, in the shop, or in a storage area. Neither is it possible to look into every nook and cranny during each inspection. However, check all components when possible, and if you find any signs of corrosion, make a thorough inspection. If you withdraw any component from an operational or storage status, go over it "with a fine-tooth comb" to determine if any corrosion has started. Look into every available spot. If you find any corrosion, stop it and prevent it from spreading. Specific areas that should be inspected closely are:

*a*. Areas of wear.
*b*. Seams.
*c*. Lap joints.
*d*. Component parts under covers.
*e*. Areas where dissimilar metals meet.

The signs to look for are dullness of a normally bright finish or the formation of a dull white or gray substance on the unfinished areas of magnesium or aluminum. Corrosion on protected or finished surfaces is indicated by a blistering or scaling of the finish. Steel turns brown and becomes rusty, and its corrosion is easy to detect.

**Control.** Use extreme caution when refinishing critical mating surfaces. Don't alter the mating surfaces from their original dimensions. The major portion of corrosion control takes place in noncritical areas and consists of a cleanup and repaint operation. If a major area of the noncritical surface shows signs of surface corrosion, use an alkaline, water-base cleaning solution. If the particular area affected is already finished and painted, remove all paint before washing.

You are exposed to highly toxic materials while using paint remover and preparing the surface for repainting. The two most commonly used substances are methyl ethyl ketone (MEK) and petroleum aliphatic naphtha. Wear rubber gloves, rubber or plastic aprons, and acid-type goggles to prevent skin or eye damage when using MEK. Use a respirator with an organic-vapor-and-dust-type cartridge when working with naphtha. In both cases, the work area should be well ventilated. Since both MEK and naphtha are flammable, keep heat and open flame away from the area. Also, if the area you are treating is adjacent to or near any part made of fiberglass, you must see that these solvents do not come in contact with the fiberglass.

Once you have removed the paint (or if you are treating an unpainted surface) thoroughly rinse the alkaline solution from the area. Use a high-pressure water hose if the metallic component is disassembled to the point where it is completely free of all subcomponents. Exercise care to ensure that any water that enters the joints is removed. In time, such moisture causes rust and corrosion on the internal surfaces of the component.

When the corrosion is not just on the surface but has also caused pitting, removing the pits becomes a more complicated task, requiring the use of scrapers or even application of acid after you wash the area. On a noncritical aluminum surface, use a metal conditioner and brightner along with an aluminum brush or aluminum wool. Clean all pits until the bottom of each pit shines. Be sure you wear protective clothing, such as rubber gloves, goggles, and an apron. After cleaning the corroded area of the aluminum, apply a suitable primer and a protective coat. (Since the specifications and procedures for using these materials are subject to change, the exact procedure is not given here. You should consult TO 1–1–2.)

Correct corrosion caused by pitting on a magnesium surface similarly. However, use an acetic nitrate pickle solution to clean the pits. Once again, wear suitable protective clothing. Use a chrome-pickle solution to prepare the surface for the primer and final finish.

**Exercises (207):**

1. List the two main steps in correcting a corrosive condition.

2. List two ways of actually correcting a corrosive condition.

3. What solution is used to clean magnesium parts affected by pitting corrosion?

4. What are the five major areas that you should inspect closely when performing an inspection on an item of equipment?

5. What is the indication that magnesium or aluminum is corroding?

6. While working on a painted camera body, you discover that a part of the camera is corroded. What steps should you take to treat the corrosion?

7. While working on a control box made from aluminum, you discover that pitting corrosion has set in. What steps should you take to treat the corrosion?

## 2-2. Equipment Preparation for Storage, Shipment, and Climate Conditions

Previously, we discussed the effect of moisture and temperature on our equipment in operation. Moisture and temperature also affect our equipment in storage or during shipment to another base or to the depot. Let us see how we can protect our equipment in storage.

### 208. Define protective measures to be observed during storage of photographic equipment.

**Storage.** Deterioration of much electronic equipment is a result of improper cleaning and storage. If you place any equipment in storage for any extended period, make sure you store it in a sealed, dehydrated container or shipping case. If such containers or shipping cases are not available, use a ventilated heat box, heated by a 100-watt lamp. You can also place bags of desiccant crystals in the bottom of the heat box to absorb any moisture resulting from the heat-draft.

To protect the equipment while in storage, place it in a self-sealing plastic bag. Place bags of desiccant crystals in the plastic bag along with the equipment. This removes any moisturized air trapped in the plastic bag during packing.

Desiccant is any substance that can attract and absorb an unusual amount of moisture from air that is sealed off from the atmosphere. Silica gel is one of the most commonly used desiccant agents. It can absorb and hold an amount of moisture equal to approximately 40 percent of its weight.

It is not enough to just make sure that storage containers are air sealed and moisture sealed. Thoroughly clean each piece of equipment before you pack it for storage. Earlier, we discussed the two basic types of corrosion-causing bacteria. Any equipment tightly packed for extended storage is highly susceptible to anaerobic bacterial corrosion; therefore, you must be certain that all equipment has been cleaned before you pack it.

**Exercises (208):**

1. If you place equipment in storage, what kind of container should you use?

2. What is a desiccant and when is it used?

3. Why must equipment be thoroughly cleaned before it is packed for storage?

4. What is the purpose of using a desiccant agent?

5. What is the most commonly used desiccant agent?

### 209. Cite protective measures to be observed during shipment of photographic equipment.

**Shipment.** It is not necessary to always pack a desiccant agent with equipment being returned to depot for repairs. The mode of transportation determines, to a great extent, the packaging method to be used.

***Air shipment.*** Pack all equipment in air- and moisture-tight shipping containers. Desiccant agent may be packed inside the shipping container but not inside the plastic bag.

All air-shipment containers must have a pressure relief valve. When you receive any equipment that has been shipped by air, always depress the pressure relief valve before you open the container. Containers subjected to a sustained high-altitude flight can have a tremendous internal pressure differential. Depending upon the difference between the atmospheric pressure at your base and the base from which the equipment was shipped, the container lid can either be held shut by a vacuum or it can be flung open with great force when you unsnap the fasteners on the container.

***Sea shipment.*** The packaging of equipment for sea shipment is similar to that for air shipment, except that desiccant must be used. The shipping containers must be airtight and watertight. Additionally, they must be made of a material such as fiberglass, which is immune to salt spray. Metallic shipping containers, exposed to salt spray conditions for extended periods, usually deteriorate to the point where they no longer adequately protect their contents.

***Surface shipment.*** The packing precautions taken for storage of sensor equipment are usually sufficient for both truck and rail shipment except that a dessicant agent is normally not needed. Again, the shipping containers must be airtight and watertight.

Regardless of the mode of transportation to be used, you must make sure the equipment is adequately packed to protect it from possible damage by vibration and rough handling. Some equipment can be permanently damaged if laid on its side. When shipping such items, be sure to mark the container with a legible stencil reading "Delicate Instrument—Handle with Care," or "This Equipment Will

Be Permanently Damaged If Not Maintained Upright," or both.

**Exercises (209):**

1. What precaution must you observe before opening a container that has been shipped by air?

2. What is the most common cause of corrosion on equipment shipped by sea?

3. What common protection must be afforded all equipment shipped regardless of the mode of transportation?

## 210. State the effects of cold temperatures on photo equipment.

**Arctic Conditions.** Most photographic operational failure in cold weather is in the shutter or lens, or it is mechanical. However, there are preventive measures that you can take to minimize the malfunctions that develop in cold weather operation. In areas subject to subzero temperatures, the most frequently encountered difficulties involve stiffness of operation, frosting of lens systems, and icing of mechanical parts. Camera mechanisms become sluggish because some lubricants thicken under extreme cold. As a result, cameras tend to bind and stick at low temperatures. As a class, electrically powered cameras are more reliable for subzero use than spring-driven types.

Projectors are subject to the same difficulties if exposed to low temperatures. However, most equipment of this type and most photogrammetric, graphic arts, photographic processing, and laboratory equipment are subject to extremes of cold only in transit and in short-term storage. (Most mobile support equipment is operable only in heated shelters.)

***Condensation.*** Your camera equipment, if it is to be used in low temperatures, should be kept in low-temperature storage (usually a protected outdoor storage place or an unheated room). Do not bring your camera systems equipment into a warm room just before a cold weather mission. When this equipment is brought into a warm room, moisture will condense from vapor in the room. This condensation, or sweating, harms camera equipment and will freeze when equipment is subjected to freezing temperatures before condensation has completely disappeared.

In arctic climates, condensation of moisture on film will occur when cold film is subjected to normal room temperature. Film to be loaded should, therefore, be removed from cold storage to a warm room 24 hours before being loaded. Film that has been brought from a cold temperature to room temperature and loaded, without allowing sufficient time for the condensed moisture to dissipate, will stick and tear when subjected to freezing temperatures. NOTE: Moisture frequently condenses on film that has been rapidly brought from high altitudes.

***Maintenance.*** All precision photographic systems equipment that is to be operated regularly at temperatures below 20°F should be winterized. For instance, two ground cameras of the same type may operate quite differently at low temperatures, since adjustment and fit of parts are of major importance. Well-broken-in equipment will not freeze as quickly as new equipment.

Each camera, including all subassemblies and individual parts, should be thoroughly washed until every trace of old lubricants and all foreign matter are removed. After washing, each part should be lubricated sparingly with a low-temperature grease or oil. All metal parts, such as housings and castings, that are subject to corrosion should be wiped with a cloth impregnated with a low-temperature oil or grease.

**Problems of Cold Temperatures.** If a camera is properly lubricated and adjusted for cool temperatures, the lens, shutter, and other parts should operate properly. The shutter of any camera will operate more slowly than normal in low temperatures. The slower speeds will cause the exposure to be incorrect. You can determine the shutter performance by testing.

***Mechanical.*** Because of contraction of metal parts, equipment tends to drag or bind when used at low temperatures.

***Lubrication.*** Lubrication should be used sparingly in low temperatures, with the type and amount in accordance with TO procedures. Too much lubrication of parts will cause drag and slower operation.

**Exercises (210):**

1. What would cause a shutter operation to be slower in cold weather operation?

2. Why should film be removed from cold storage 24 hours before loading?

3. What procedures should be accomplished on photo equipment when operated regularly below 20°F?

## 211. Specify how to handle photographic equipment in the tropics.

**Tropical Operation.** The distinctive characteristics of all tropical climates are high temperatures, high humidity, abundant rainfall, and sunshine. Indirectly these influence nearly every form of deterioration associated with the tropics—moisture for accelerating chemical reactions, growth of fungi, and the continuous exposure to the strong actinic rays of the sun.

***Mechanical problems.*** Corrosion of metals is accelerated in the tropics. Corrosion is caused by various conditions that were covered earlier. Remember that it is accelerated by a humid atmosphere, fungus growth, salt water air and spray, coral dust, soil, acids, bacteria, and insects secreting organic acids. Even though the equipment may be protected by the manufacturer with special plating, alloying, painting, etc., and at times by combinations of these measures, use of the equipment and the necessary repairs tend to depreciate the protection. The amount of corrosion is inversely proportional to the effort expended in organizing a corrosion-control program.

Severe corrosion usually occurs within a few days under tropical conditions. Make frequent and detailed inspections to ensure efficient corrosion control. Make it a standard practice to inspect, clean, and lubricate all moving parts of electronic sensors as often as possible. Avoid leaving fingerprints on lens surfaces or on other parts The residue from fingerprints will furnish food for fungi.

***Electrical problems.*** Insects are often the cause of equipment failures. Many kinds of insects are attracted by waxes, varnishes, or rubber used in electronic equipment. For example, termites eat their way into coils and other electronic components. They usually die in the equipment, and their bodies become both paths for short circuits and food for fungi. Spiders may spin webs in the equipment. Then dew collects on the webs and causes short circuits. Screens, filters, and either dust or spray forms of insecticide control most insects.

The main types of electronic equipment malfunctions due to high temperature and high humidity are:

*a.* Corrosion of contacts.

*b.* Moisture in coils—fluctuation of frequency, short circuits, and burned out coils.

*c.* Filter capacitors and transformers shorting and burning out.

*d.* Deterioration of rubber on power cables—shorts.

*e.* Rusting and corroding of exposed metal.

*f.* Short circuiting of dynamotors and generators.

*g.* Leakage of wires that have been formed into laced cables.

*h.* Lowering of capacitor leakage resistance.

*i.* Transformer failures due to breaks in windings.

*j.* Relay failures due to increased resistance to movement of their cores.

***Protective measures.*** When air conditioning or heated storage cannot be provided for equipment, try to get a maximum amount of ventilation. Photographic equipment requires special attention in the tropics because it deteriorates rapidly and often fails because of moisture absorption, condensation, fungus growth, and corrosion. The general maintenance practices necessary to guard against damage and deterioration of photographic equipment and supplies are as follows:

*a.* Keep the equipment dry.

*b.* Keep the equipment clean.

*c.* Keep the equipment well ventilated.

*d.* Keep the equipment properly lubricated.

*e.* Keep film and parts in the factory wrappings until they are ready to be used.

**Exercises (211):**

1. List four distinctive characteristics of tropical climates.

2. What is the main mechanical problem in tropical operations?

3. List at least six items that accelerate corrosion.

4. Why should you avoid leaving fingerprints on lens surfaces?

5. In what way do insects contribute to system failures?

6. In what way do spider webs contribute to system failures?

7. List 10 types of electronic equipment malfunctions caused by high temperature and high humidity.

8. What must you do to protect equipment in tropical conditions?

### 212. Specify how to handle, store, and protect photographic equipment in the desert.

**Desert Operation.** Desert regions of the earth are characterized by high day temperatures, low night temperatures, little rainfall or moisture, and large quantities of loose, fine dust and sand blown about by wind. Deterioration results from the high daytime temperatures, ultraviolet radiation, sand, dust, and the large daily temperature fluctuations. Of all these, the sand and dust particles are usually the most serious. If these particles get on the lens or film, they also act as abrasives and grinding agents when they get into working mechanisms or lubricants.

***General problems.*** The intense heat and bright sunlight of the desert areas cause rubber to crack and deteriorate and may cause equipment to overheat, increasing the failure rate of certain electronic components. If air conditioning is not available, schedule both the maintenance of the system and the checks requiring extended operation to be done at night when possible.

***Mechanical problems.*** All camera mechanisms are extremely sensitive to dust and sand, causing them to stick. Protect the sensor equipment from dust and corrosion by frequent inspections and cleanings. Store equipment that is not in use in a clean, dry, cool place. (Cover the case with a tarpaulin to help keep out dust and sand.) Keep caps on all lens surfaces when the lenses are not in use.

***Electrical problems.*** The wide variation of temperature in desert climates reduces the life of electronic equipment and affects its performance. Most types of seals on electronic equipment such as transformers and capacitors will deteriorate, exposing fine wires and dielectrics. Dry-cell life and performance are greatly impaired by the high temperatures common to the arid regions. Keep these items in their original packaging until you are ready to use them. Dust causes faulty operation of variable condensers. Most exposed relays become inoperative under conditions of heavy dust. The dust particles cause short circuits, arcing, and sticking if the points are not cleaned before use. Frequently check vacuum tubes that are exposed to extremely high temperatures.

***Protective measures.*** Endless cleaning, inspection, alertness, and hard work are necessary to keep equipment clean and serviceable. You are aware of the photographic problems caused by ordinary dust, but you must also realize that numerous particles anywhere from 0.02 millimeter to 0.2 millimeter may be driven into exposed operating mechanisms. When these particles combine with the lubricating oil, they wear down close-fitting parts and create a fit that is too loose for correct operation.

**Exercises (212):**

1. List four characteristics of desert climates.

2. Which of these is usually the most serious?

3. If air conditioning is not available, when should maintenance on the system be accomplished?

4. List three characteristics of the place where equipment should be stored.

5. List three electrical problems encountered in desert climates.

6. What major damage is caused by dust mixed with lubricants on moving parts?

7. What must you do to protect equipment in desert conditions?

## CHAPTER 3

# Principles of Photography

IN REPAIRING precision photographic systems, you must know enough about precision photography to operate equipment and check effectively both the products of the various items of photographic equipment and the equipment itself. Therefore, you must understand the principles of precision photography to the point where you can think and talk intelligently about it. The material in this chapter will review and expand upon the limited information you received on photographic principles in your training from the helper level to the apprentice level.

The precision photographic principles presented in this chapter include a discussion of photographic fundamentals, sensitized materials, processing sensitized materials, printing methods, and optical systems.

### 3-1. Photographic Fundamentals

As you know, photography is required for many purposes in the Air Force. Military and civilian personnel must be photographed for identification and publicity purposes. All new construction is photographed at regular intervals to record progress. Valuable documents and maps are copied so that the originals may be protected against excessive wear and tear. Under combat conditions, aerial mapping and reconnaissance photos must be processed so that the adequacy of gunners and fighter pilots can be checked.

These are but a few of the many military uses of photography. They are sufficient, however, to give you an idea of the importance of photography and the necessity for high performance of processing equipment. To keep the processing equipment in excellent condition at all times, you must possess knowledge of certain photographic principles. With this knowledge, you will be able to analyze the resultant photograph intelligently to determine if the equipment is functioning properly. In other words, you must learn what elements contribute to making a good picture. To help you gain this knowledge, we shall first explain the photographic theory and then tell you what happens when you make a photograph.

**213. Define the different terms associated with the nature of light, and specify the approximate wavelengths which excite different color sensations.**

**Light.** There are three basic steps in making a photograph. The first step is to expose the film. When the camera shutter is tripped, radiant energy that is reflected from the subject is allowed to enter the camera as long as the shutter is open. The film emulsion contains very small particles of radiant-energy-sensitive silver salts. The returning radiant energy from the subject exposes these silver salts. Photography is made possible by the action of radiant energy on the sensitized emulsion. Thus, radiant energy and emulsion are the basis of photography.

Now that you know that conventional photography is the recording of an image on light-sensitive material by the action of radiant energy, let's discuss the properties, characteristics, and peculiarities of light.

Light is a form of radiant energy that radiates in all directions from its source. By radiant energy we mean any form of energy radiating from a source —such as electromagnetic waves, sound, heat, light, X-rays, and gamma rays. Like other forms of radiant energy, light travels in waves of varying length. The wavelength of the light determines its color and is measured as the distance between corresponding parts of two consecutive waves, as shown in figure 3-1.

The direction of the wave front (wave front being the radiation of waves similar to the waves generated from a pebble being thrown into a pool of water) is represented by a straight line. This line is shown in all optical diagrams, such as those showing the function of a lens, and represents the radius of the wave front radiating from the point of source. It is termed "ray" of light, as shown in figure 3-2.

Another term for light wave is "frequency." Frequency of light is the number of waves that pass a fixed point in a given unit of time. If you drop a pebble in a pool of water, waves radiate out from the point where the pebble entered the water. If you pick

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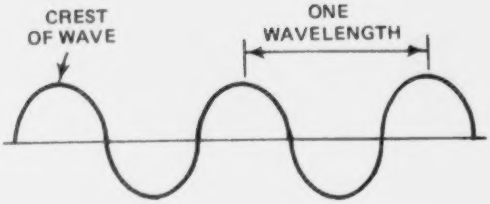

Figure 3-1. Measurement of wavelength.

a certain point on the surface of the pool and count the waves passing that point during a period of 10 seconds, for example, you can establish a frequency of sorts.

Although the human eye can see visible radiant energy, it cannot see the other portions of the spectrum such as the previously mentioned radio, X-ray, gamma, etc. For this reason the term "light" is generally restricted to the portion of the electromagnetic spectrum that the human eye can see. The electromagnetic spectrum is illustrated in figure 3-3. The upper portion of the illustration shows you the entire spectrum. The lower portion of the illustration is an enlarged view of the visible light portion. Visible light occupies just a small portion of the total spectrum and consists of wavelengths from about 400 to 700 nanometers. A centimeter is one-hundredth of a meter, a millimeter is one-thousandth of a meter, a micron is one-thousandth of a millimeter, and a nanometer is one-millionth of a millimeter, or one-billionth of a meter. Since a millimeter is only one twenty-fifth of an inch, you can see that the 700-nanometer dimension is extremely small. A nanometer is expressed by the symbol "nm."

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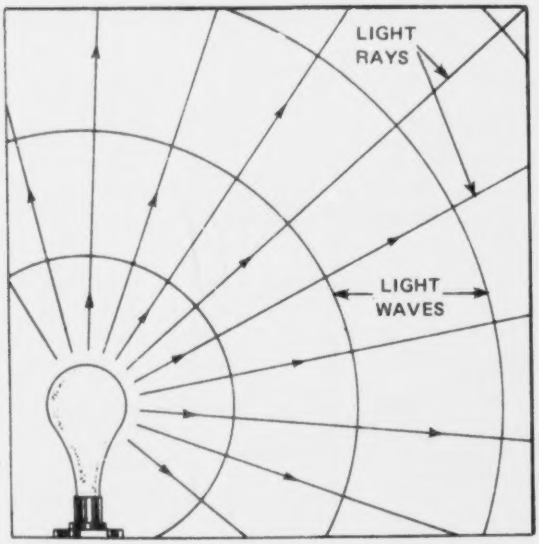


Figure 3-2. Light travels in direction or radii of waves.

Viewing the entire range of wavelengths in the visible spectrum (from 400 to 700 nm), you have the sensation of seeing color. The approximate wavelengths that excite color sensations are as follows:

| | |
|---|---|
| Violet | 400 - 450 nm |
| Blue | 450 - 500 nm |
| Green | 500 - 580 nm |
| Yellow | 580 - 590 nm |
| Orange | 590 - 620 nm |
| Red | 620 - 700 nm |

If you see various combinations of wavelengths, you have the sensation of seeing different colors. Red, blue, and green are called primary colors. All other colors are combinations of varying amounts of the primary colors. If there is more red than green, the sensation is orange. You will understand this fact better when you have studied the discussion on filters. The position of all colors in the visible spectrum can be seen in figure 3-3.

**Exercises (213):**

1. Define the following terms associated with light.
   a. Wavelength.
   b. Radiant energy.
   c. Frequency.

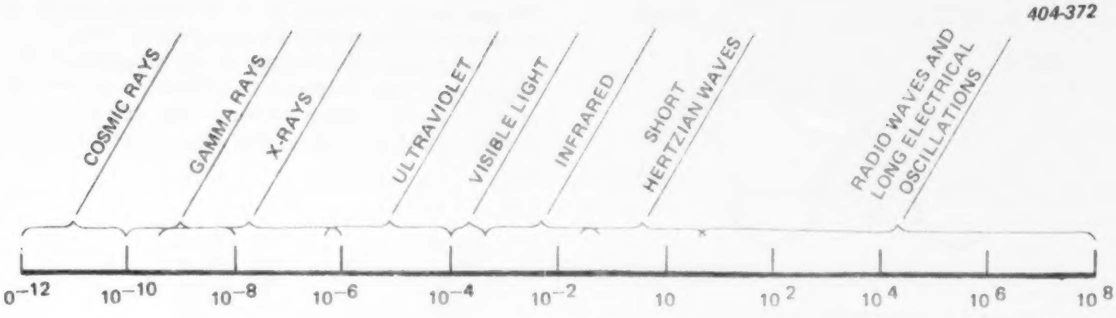
2. What does the wavelength of visible light determine?

3. Match the following colors to the correct wavelength.

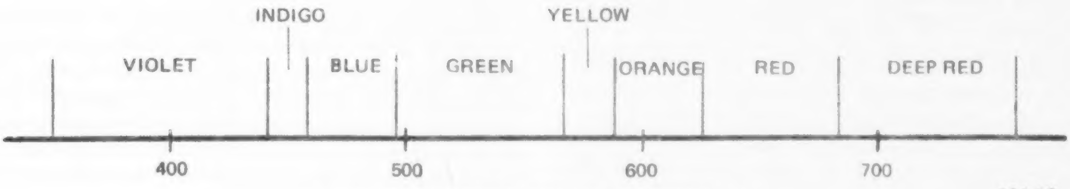
| *Column A* | *Column B* |
|---|---|
| ____ (1) Violet | a. 580 - 590 nm |
| ____ (2) Yellow | b. 400 - 450 nm |
| ____ (3) Orange | c. 620 - 700 nm |
| ____ (4) Red | d. 590 - 620 nm |
| ____ (5) Blue | e. 450 - 500 nm |
| ____ (6) Green | f. 500 - 580 nm |

**214. Define or specify the different terms associated with behavior of light.**

**Behavior of Light.** Because light is used to make a photographic exposure, you must know something



A. λ IN CENTIMETERS



B. WAVELENGTH IN MILLIMICRONS (mu)

Figure 3-3. Wavelength in centimeters and millimicrons (nanometers).

about the speed of light, reflections, transmissions, absorption, refraction, dispersion, diffraction, color, and polarization. To be a good specialist, you must understand these terms and their principles.

*Speed of light.* The speed of light in its flight through space is so fast that it defies imagination. The moon is approximately 384,000 kilometers (240,000 miles) from earth, yet light can span the gap in less than two seconds. Light travels through space at approximately 300,000 kilometers (186,300 miles) per second. As light travels through denser mediums, such as glass or water (as compared with air), its speed is decreased. Speed of light is constant in any medium of given density, but its speed changes as the waves pass from a medium of one density to a medium of different density. This is shown in figure 3-4.

*Reflection.* The change in direction of light after striking a surface is called reflection. Light striking the surface is called incident light. If the surface the light strikes is smooth and polished, reflected light bounces off the surface in the same plane and at the same angle as the incident light. The reflections from smooth, polished surfaces are said to be specular. However, if the surface is rough and irregular, the light is reflected in more than one plane and direction. This reflected light is said to be diffused. Study the differences in the two types of reflected light in figure 3-5.

The amount of light reflected by any surface depends, to a great degree, on the color of the surface. Black or dark surfaces, for example, absorb much of the light and reflect verv little. White or bright surfaces, on the other hand, reflect a greater amount of light. This has a bearing on photography, since the amount of radiant energy received by the sensitized material will determine the exposure of the silver halide salts. Since most objects reflect both specular and diffused light, the diffused reflected light forms the shadows in photographs, while the specular reflected light creates the very bright highlights.

If the incident light strikes the plane at a 90° angle (perpendicular), the reflected light will be directed back along the path of the original beam. This path, which is an imaginary line perpendicular to the plane

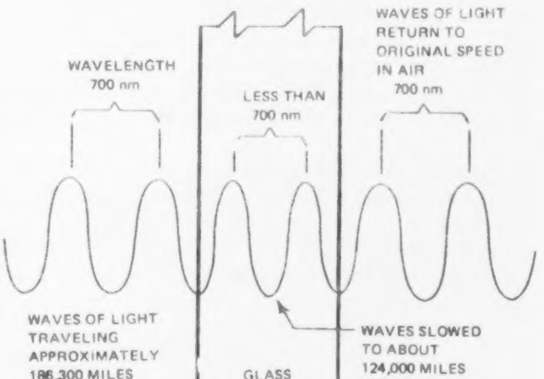


Figure 3-4. Variations in speed and wavelength.

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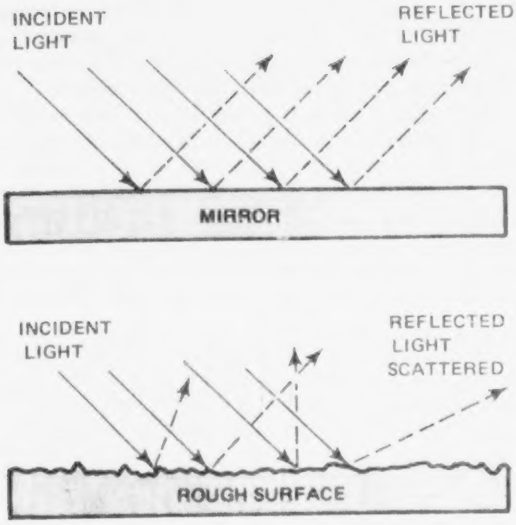

Figure 3-5. Reflection.

surface, is called the *normal* or *perpendicular* (fig. 3-6).

If the incident light strikes the plane at an angle other than 90°, the light will be reflected at an equal angle away from the direction of impact (fig. 3-6). In this case the angle formed by the incident light and the perpendicular (called the angle of incidence) is equal to the angle formed by the reflected light and the perpendicular (called the angle of reflection.)

*Transmission*. The term that describes the passing of light through a medium is transmission. For transmission to take place, the medium must be either transparent or translucent. A transparent medium will transmit rays of light through its substance, and any object beyond or behind the medium can be distinctly seen. Figure 3-7 shows that transparent mediums do not give 100 percent transmission. Translucent mediums transmit rays of light, but alter their direction of travel. An object beyond or behind a translucent medium cannot be seen distinctly. Transmitted light through a translucent medium is diffused. If a medium is neither transparent nor translucent, it is opaque. Light cannot pass through an opaque medium. Observe figure 3-8 and note the difference between transparent, translucent, and opaque mediums.

*Absorption*. When light is neither transmitted nor reflected by a medium, it is absorbed. Black objects, such as black cloth, black ink, or black covers, appear black because they reflect very little light. On the other hand, white objects, such as white paper and snow, appear white because they reflect most of the incident light.

*Refraction*. The bending of a ray of light is called refraction. As light passes from a medium of one density to another medium of a different density, its speed is altered. For example, the speed of light through ordinary glass is approximately 192,000 km (120,000 miles) per second. The rates between the

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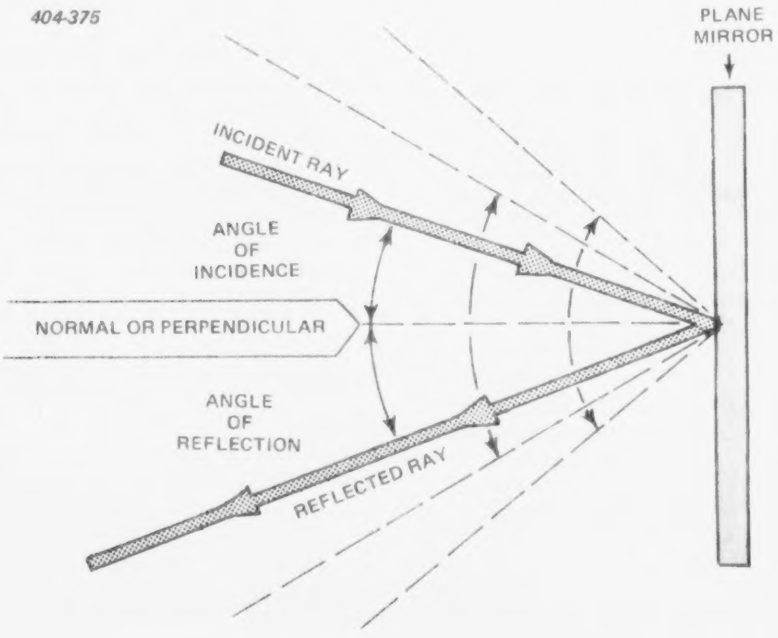


Figure 3-6. Terms pertaining to reflected light.

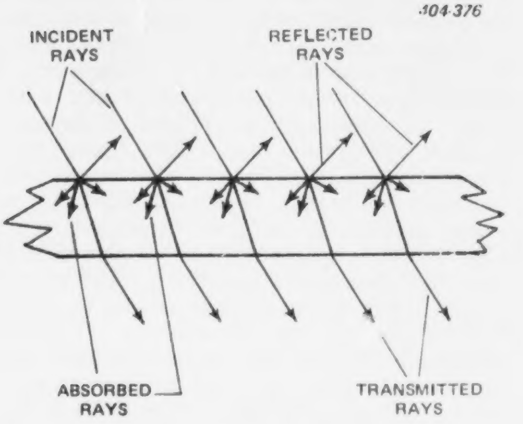


**Figure 3-7.** Reflection, transmission, and absorption of a single medium.

speed of light through air and the speed of light through the second medium are known as the index of refraction.

If the ray of light strikes the new medium perpendicularly (90°) to its surface, it passes through with no appreciable change in direction. This type of ray is called a normal ray, and the angle the ray makes with the surface of the medium is called the normal angle, or simply, the normal.

If the ray enters the new medium at an oblique angle, it is bent or refracted. Figure 3-9 demonstrates the principle of refraction. The law of refraction states that "if light enters a medium of different density at an oblique angle, its direction is changed so that the light is bent toward the norm if the medium is more dense and away from the norm if the medium is less dense than the first medium."

Refraction makes it possible for a lens to form a sharp image of an object. Light can be bent and directed in any direction and to any degree by (1) controlling the shape of the surfaces of the medium (flat, convex, or concave), (2) calculating the correct relationship of the surface of the medium, or (3) choosing the medium which has the correct density to accomplish the desired effect (flint glass, air, crown glass, etc.).

*Dispersion*. The variation of the refractive index in relation to the variation of the wavelength of light (increasing as the wavelength decreases) is known as dispersion. As illustrated in figure 3-10, dispersion is also the name given to the separation of white light into its constituent colors. It causes the prism spectrum (the rainbow appearance of light passing through a prism). Any ray of white light that strikes a prism at the proper angle is separated into violet, blue, green, yellow, orange, and red light. This is a problem in designing lenses. If it is not corrected, the various components of light that make up the total image do not focus in the same plane.

*Diffraction*. When light passes over the edge of an opaque medium, it is scattered slightly. This scattering of light is called diffraction. Figure 3-11 shows an exaggerated effect of diffraction. You can see dif-

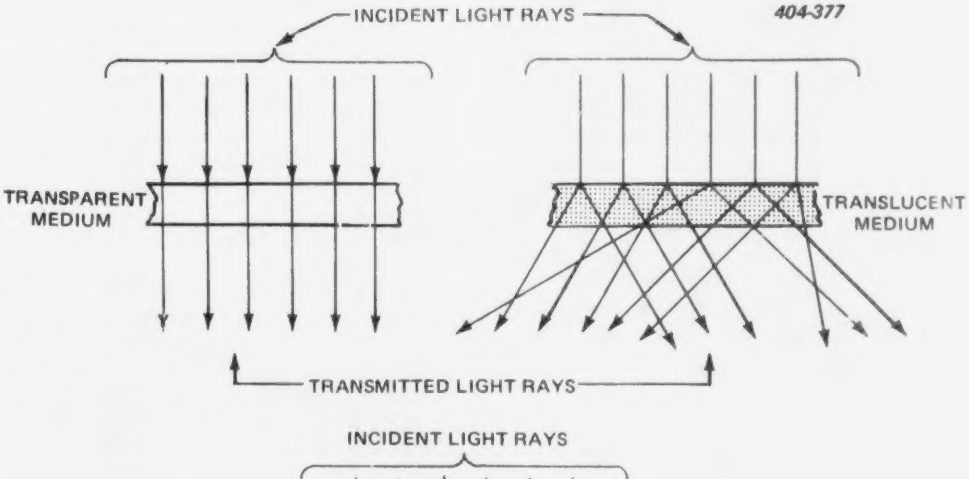


**Figure 3-8.** Transparent, translucent, and opaque mediums.

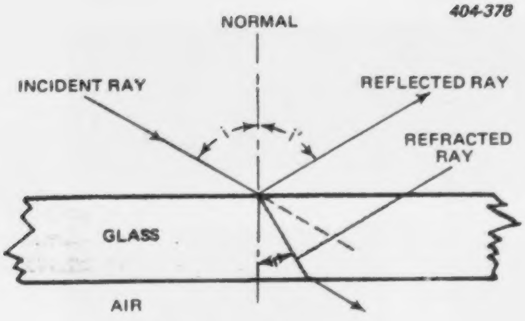


Figure 3-9. Refraction.

fraction as a shadow with a fuzzy edge when an opaque object is placed so that it partially blocks the path of the rays from a point source of light. The outside edge of the shadow is light and indistinct. It gradually fades into the deep black of the shadow. Some of the light is scattered into the shadow area. In photography, diffraction takes place as light passes over the opaque edge of the diaphragm in the lens and shutter system.

*Color*. Objects appear to have color because they reflect and absorb light selectively. For example, an object appears red when light falls upon it because (1) there is some red in the incident light and (2) the object has the ability to reflect the red portion of the visible spectrum and to absorb the other portions. If the object is viewed under pure red light, it still appears red. However, if you observe the same object under pure blue light, it appears black.

Why does it appear as red or black under the conditions mentioned? Since the source mentioned contains only one color, the reflecting and absorbing characteristics of the object determine what the eye sees. When it reflects the red light, the light is visible. When it absorbs the blue light, the light is not visible. It stands to reason that a red light source contains red and the object itself reflects wavelengths in the vicinity of 700 nm and absorbs other wavelengths.

*Polarization*. Another useful characteristic, photographically speaking, is that light can be polarized, or filtered, to vibrate in only one plane. Ordinarily, a ray of light is considered to vibrate in all planes perpendicular to direction of travel. If desired, the light can be polarized by means of special filters or through maximum use of natural polarization.

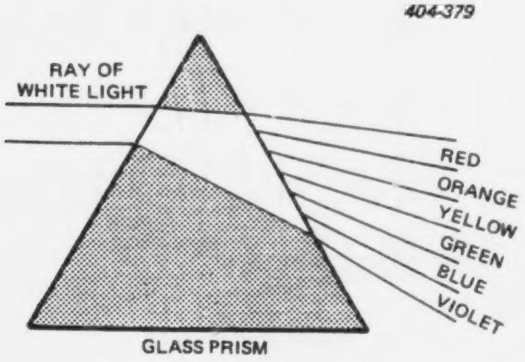


Figure 3-10. Dispersion.

Manmade polarization is achieved with a polarizing filter over the light source and/or over the camera lens. Nature polarizes light, but the conditions under which it is polarized are very limited. First, light reflected from a nonmetallic surface is naturally polarized at an angle of approximately 35°. (There is also some polarizing effect at angles other than this, but the effect is gradually diminished until there is no polarization at 0° or 90°.) Light reflected from a metallic surface is not polarized. Second, light from a clear blue sky at right angles to the sun's rays is also polarized by nature. (This effect diminishes toward 0° and 180°.)

Figure 3-12 illustrates the principles of polarization. The illustration on the left shows natural polarization. The illustration on the right shows how two polarizing filters affect light while one filter axis is gradually rotated until it is perpendicular to the first filter. Light that vibrates in only one plane is plane polarized. It is impossible to distinguish plane-polarized light with the unaided eye. This is why its rather frequent occurrence in nature is generally unknown.

Exercises (214):

1. What is meant by speed of light?

2. What factor influences the speed of light?

3. Define reflection.

4. What is meant by transmission?

5. Identify the following mediums as being transparent, translucent, or opaque.
   a. Camera ground glass.
   b. Window pane.
   c. Piece of cardboard.

6. The bending of light rays is called what?

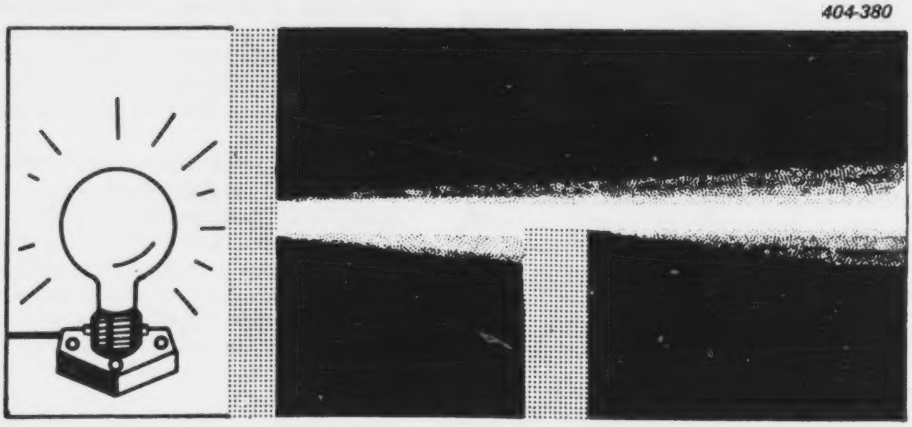


Figure 3-11. Diffraction.

7. Retention of light by a medium (not reflected) is _________.

8. The separation of white light into its component colors is possible only through _________.

9. What is polarized light?

## 3-2. Lens Characteristics

The optical term "lens" is applied to a piece of glass that is bound by two spherical surfaces or a plane and a spherical surface. It is also commonly used when referring to a photographic objective. The term "photographic objective" indicates that several simple lenses have been combined as elements in an optical instrument that is used to form a real image of an object.

The lens has many principles that are peculiar to photography. Each of these principles or optical laws has been named. If you, as a precision photographic specialist, wish to make the best use of the lens, you should be thoroughly acquainted with these principles and terms. Consequently, a discussion will follow each of the terms considered to be the most important.

**215. State the principle by which a lens produces an image and the factors that determine the image size, brightness, and sharpness on the film plane.**

**Principle of a Lens.** The basic principle of lenses is relatively simple. First consider the image formed with a single pinhole, as shown in figure 3-13. Now consider another pinhole above the first. This pinhole forms a second, but displaced image. If the

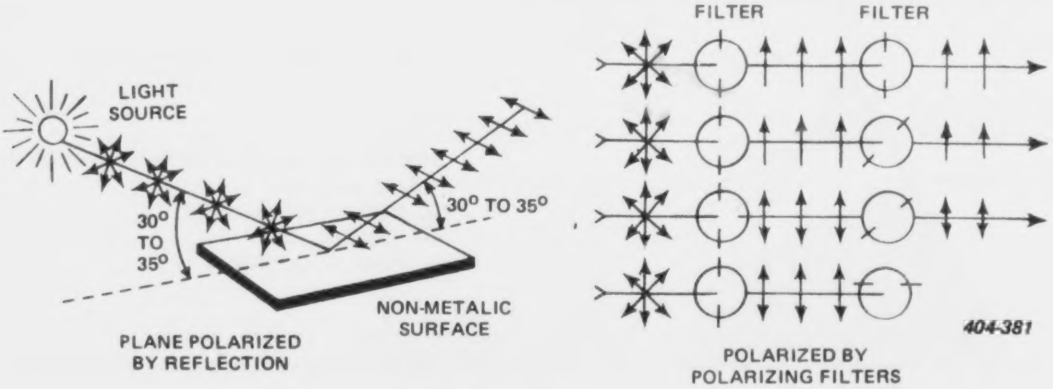


Figure 3-12. Polarization.

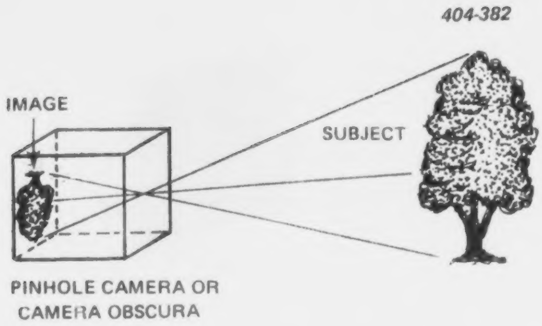


Figure 3-13. Inverted image created by a pinhole camera.

two images were made to coincide, there would only be one image, twice as bright as either image by itself. Now consider a third pinhole on one side of the first, then a fourth on the other side, and a fifth below the first. Each of the five pinholes would project an image that was displaced from the other four images. This is shown in figure 3-14. If these five images could be made to coincide, the resultant image would be five times as bright as any image formed by a single pinhole.

Through the principle of refraction, these five images discussed in the previous paragraph can be superimposed. Behind each of the four perimeter pinholes is placed a prism whose surfaces are cut and ground to refract each image the correct amount to superimpose all five images. The result of this is one image five times as brilliant as a single pinhole image. This principle is illustrated in figure 3-15.

Applying the aforementioned principle, you can see that the more pinholes and the more prisms used to form an image, the brighter the image becomes. A system could be made by using an infinite number of pinholes and prisms positioned around a single pinhole and, in effect, a lens would be produced. Of course, such a lens would be cumbersome, difficult to manufacture, full of aberrations, and prohibitive in cost. The problem was solved by the construction of a lens from a single piece of glass. The lens represents an infinite number of pinholes or prisms or a continuous prism in circular form. This type of circular prism (or lens) eliminates the necessity of having pinholes, because the lens itself forms the image in the same manner as do two prisms placed base to base, as illustrated in figure 3-16.

Further improvement came about when the adjustable opening (diaphragm) was incorporated into the lens system. When the opening was made larger, more light was allowed to pass through the lens; when it was made smaller, less light was allowed to pass. A lens not only increases the brightness of the image, but it also improves the image sharpness and enables the user to control the size from specific distances. Brightness of the image is improved by controlling lens speed, image sharpness is improved through the minimizing of diffraction, and image size is controlled by the focal length.

**Exercises (215):**

1. What principle is used to bend light rays so that they form a single image?

2. What determines the brightness of the image formed at the film plane?

3. What determines the image size on the film plane?

4. How can image sharpness be improved on the film plane?

**216. State the laws that affect the light passing through various types of lenses and state the lens type from the lens description.**

**Prisms.** When a ray of light passes through a sheet of glass, it emerges parallel to the incident light. This holds true only when the two surfaces of the glass are

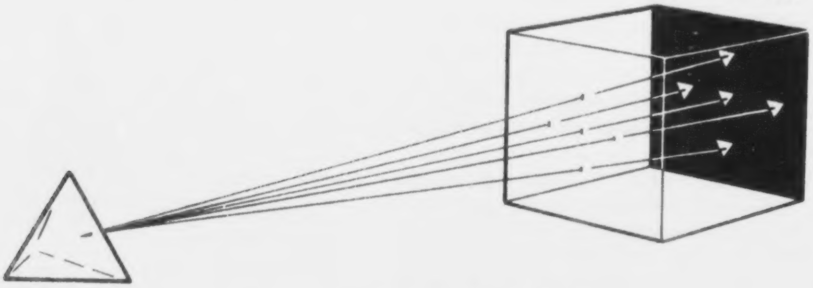


Figure 3-14. Separate images of same subject.

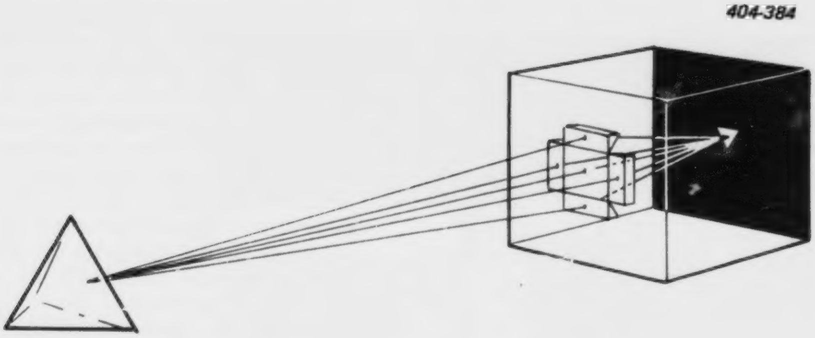


Figure 3-15. Separate images made to coincide.

parallel. When the two surfaces are not parallel, as in a prism, the rays will be refracted at each surface of the glass.

Figure 3-17 shows that both refractions are in the same direction and that the emergent ray is not parallel to the incident ray. The law of refraction explains what happens. When the ray entered the prism, it was bent toward the normal, and when it emerged it was bent away from the normal. However, the two normals are not parallel. The angle between the incident ray and the emergent ray is the deviation angle of the prism. Notice that the deviation is the result of the two normals not being parallel.

If two triangular prisms are placed base to base, as in figure 3-18, parallel incident light rays passing through them will be refracted and caused to intersect. The rays passing through different parts of the prisms, however, will not intersect at the same point. In the case of the two prisms, there are only four refracting surfaces, and the light rays from different points on the same plane will not be refracted to a point on the same plane behind the prism. They will emerge from the prism and intersect at different points along an extended common baseline, as illustrated by points A, B, and C of figure 3-18.

Parallel incident light rays falling upon two prisms that have been joined apex to apex (fig. 3-19) are spread apart. The upper prism refracts light rays falling upon it upward toward its base, and the lower prism refracts light rays downward toward its base, causing the two sets of rays to diverge.

**Positive Lens.** Suppose two prisms are placed base to base, as shown in figure 3-18. The upper prism refracts the light downward toward its base, and the lower prism refracts the light upward toward its base. If the light rays are parallel to the prism bases, they will cross each other.

A positive, convergent lens acts like two prisms base to base with their surfaces rounded off into a curve. Rays that strike the upper half of the lens bend downward, and the rays that strike the lower half bend upward. A good lens causes all wavelengths within each ray that is reflected from an object in

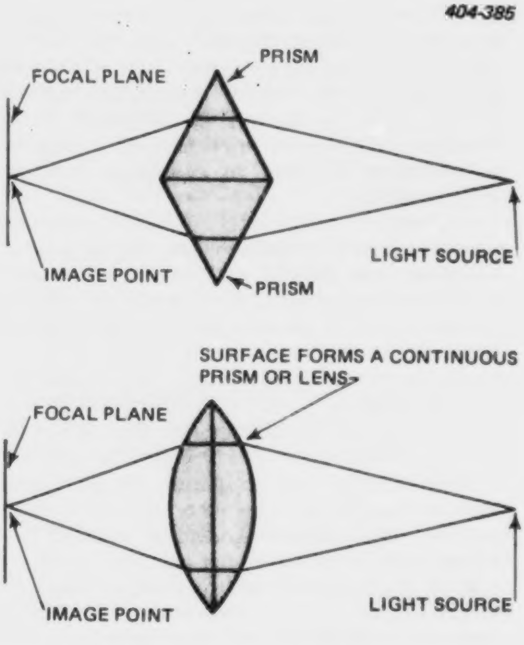


Figure 3-16. The lens principle.

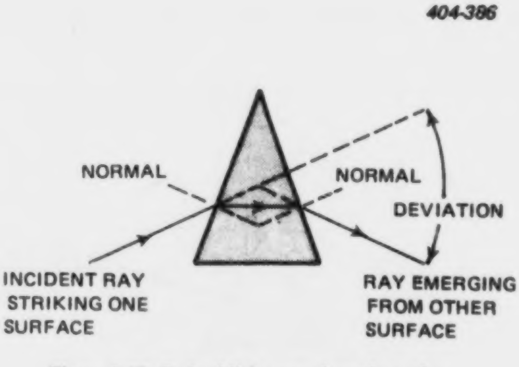

404-386
NORMAL
NORMAL
DEVIATION
INCIDENT RAY STRIKING ONE SURFACE
RAY EMERGING FROM OTHER SURFACE

Figure 3-17. Path of light rays through a prism.

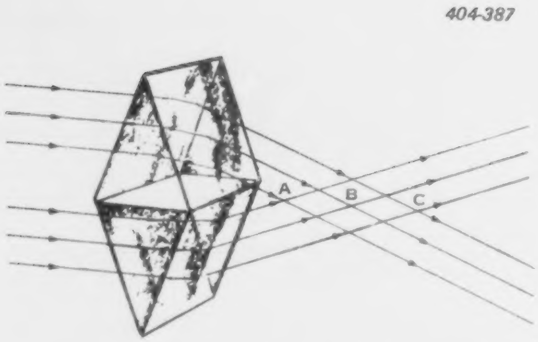


Figure 3-18. Refraction of light by two prisms base to base.

front of the lens to cross at the same point behind the lens, as shown in figure 3-20.

To understand the effect upon a ray of light passing through a positive lens, apply the law of refraction. When the incident ray of light enters the denser medium (the lens), it bends toward the normal. When it passes through into the less dense medium (the air), it bends away from the normal. Figure 3-21 illustrates the refraction of only one ray, but any number of rays passing through a positive lens are affected in the same manner. Refer to figure 3-20 and note the path of the center ray as it passes through the positive lens. All incident light rays, either parallel or slightly diverging, converge to a point after passing through a positive lens.

The only ray that can pass through a lens without bending is shown in figure 3-22. This ray strikes the first surface of the lens at a right angle, perpendicular or normal to the surface. Therefore, it passes through the surface without bending. It strikes the second surface at the same angle; therefore, it leaves the lens without bending. Rays passing straight through a lens at an angle normal to both surfaces will not bend. The converging or positive lens bends all other rays passing through it toward the incident axial ray.

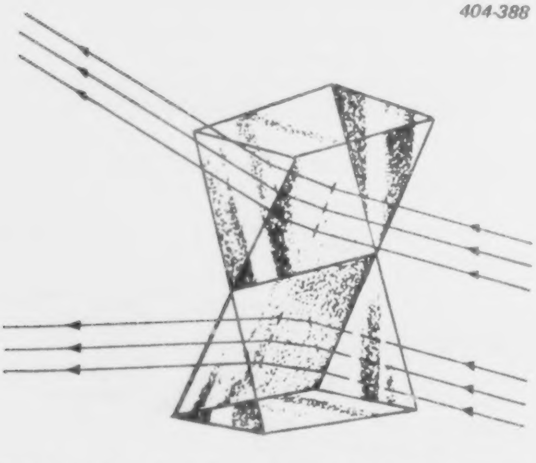


Figure 3-19. Refraction of parallel light rays by two prisms apex to apex.

The terms "positive lens" and "convergent lens" are synonymous, since either of them may be used to describe the action of a lens that focuses (brings to a point of convergence) all light rays passing through it. All simple positive lenses are thicker in the center than at the edges, and (either individually or as combinations of simple lenses in positive form) they all have the power of converging light rays. Positive lenses are used to form the real image that is recorded with a camera.

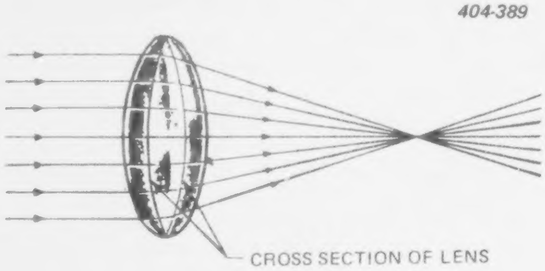


Figure 3-20. Refraction of light rays by a positive lens.

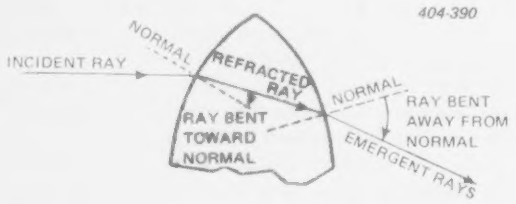


Figure 3-21. Law of refraction applied to a convergent lens.

Originally, photographic lenses were simple positive lenses. These simple positive lenses are used in some of the cheaper cameras today, but in most cases the lenses are composed of two or more simple lenses to obtain satisfactory results with modern, all-color-sensitive photographic film.

A positive lens has a convex shape, and when two or more of these lenses are combined to form a compound lens, the simplest positive lens is then called a lens element. The positive lenses are easily identified by their pronounced shapes, since they are thicker through the center than at the edges. The three most common simple positive lenses are shown in figure 3-23. They are the double-convex, plano-convex, and the concavo-convex, which is also known as the positive meniscus (crescent shape).

**Negative Lens.** Figure 3-19 illustrates the refraction of light rays by two prisms apex to apex. If the prism surfaces are rounded, the result is a negative diverging lens, as shown in figure 3-24. The ray passing through the center of the lens does not bend, while the other rays are refracted away from the center of the lens.

A negative lens is also defined as a divergent lens, since it does not focus the rays of light passing through it. Light rays passing through a negative lens diverge or spread apart, as shown in figure 3-24.

Figure 3-25 shows the application of the law of refraction as it affects one ray passing through a negative lens.

Simple negative lenses are used in conjunction with simple positive lenses in modern day cameras.

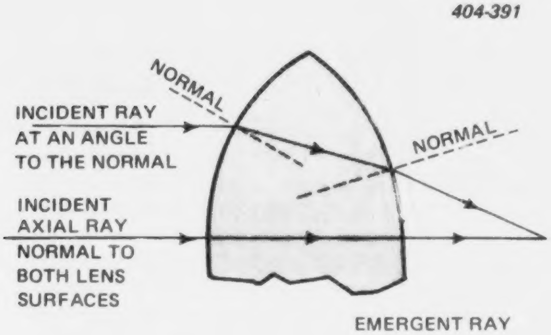


Figure 3-22. The path of an incident light ray on a lens.

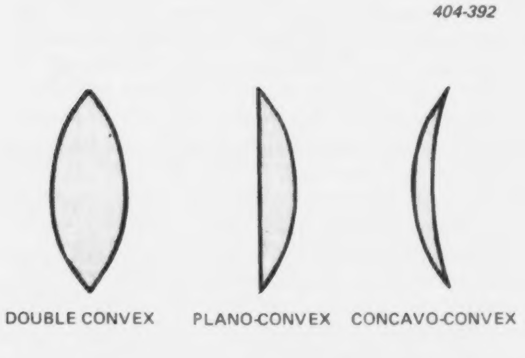


Figure 3-23. Three simple positive lenses.

Their primary use in a formula is to assist in the formation of a sharper image by helping to eliminate or subdue the various defects and aberrations present in an uncorrected simple positive lens. These defects and aberrations will be discussed later in this section.

A negative lens refracts light in such a way that the rays are spread out or diverged. Diverging lenses are often referred to as concave lenses and are readily identified by their concave surfaces. The simple negative lenses are thicker at the edges than in the center. They are the double concave, plano-concave, and convexo-concave, which is also called the negative meniscus. The negative lens forms are shown in figure 3-26.

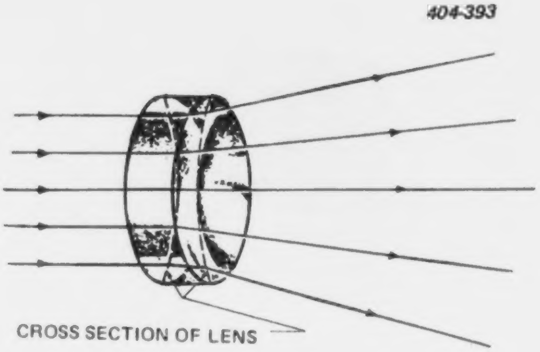


Figure 3-24. Refraction of light by a diverging lens.

The negative lens forms a virtual image, but it cannot be projected or focused on a screen. However, it can be seen with the eye, which is basically a positive lens, and can be photographed with a camera since the camera lens is also positive in form. The principle use of the negative lens, when mounted alone on a camera, is for direct vision viewfinders. The only other photographic purpose it serves is as an element in conjunction with positive lens elements in compound lenses.

**Exercises (216):**

1. State the law of refraction as it applies to a prism, a positive lens, and a negative lens.

2. What type of lens is a plano-convex?

3. What type of lens is the plano-concave?

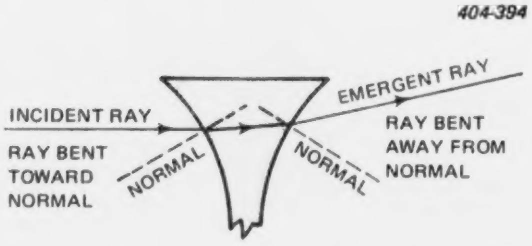


Figure 3-25. Law of refraction applied to a diverging lens.

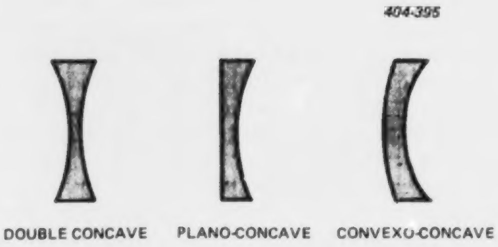


Figure 3-26. Three simple negative lenses.

**217. Given a list of image defects, identify the lens aberration that produces each defect and specify how each is corrected.**

**Lens Aberrations.** In the previous discussion, we mentioned that various defects and aberrations in simple lenses had to be corrected to obtain a sharp image. Lens defects are normally flaws in the glass that result from manufacturing carelessness. These defects are not within our control or correction, but the defects caused by aberration can be minimized when the lenses are assembled.

In some books aberrations are called lens defects. Aberrations are not caused by manufacturers' carelessness, but are caused by the ways in which the behavior of light affects image formation by the lens. A few of them are present to some degree in the better modern lenses.

A compound lens may, for various reasons, contain an aberration which is common to a simple thin lens. Therefore, you should learn something of these aberrations—how to identify them and, when possible, how to correct or subdue them.

*Chromatic aberration.* The inability of a simple lens to bring all the colors of the visible spectrum to the same plane of focus is called *chromatic aberration*. Figure 3-27 shows a lens that is not corrected for chromatic aberrations. It focuses the various colors of the spectrum on different planes even though they originate from the same source. This aberration forms color fringes around the image points, which represent points on the subject if the subject reflects complex light. Not all colors are of equal sharpness on the same plane, and unless a single color is being recorded, the lens with chromatic aberrations cannot function satisfactorily.

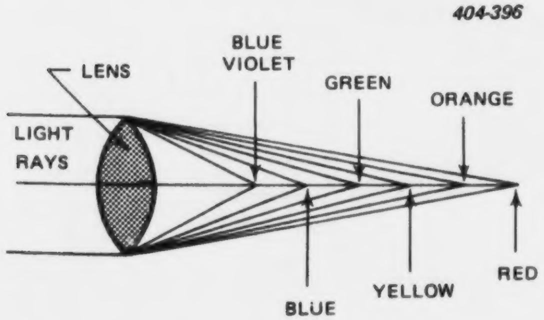


Figure 3-27. Chromatic aberration.

This difficulty cannot be overcome in a simple lens, but it may be reduced by using a smaller aperture. A correction for this aberration is made when the compound lens is constructed by placing a simple negative lens in optical contact with a simple positive lens. This combination allows the longer wavelengths to be refracted more sharply and the shorter wavelengths to be refracted less sharply. This allows all colors to be focused near the same plane.

*Astigmatism.* The inability of a lens to bring together at a common plane of focus both horizontal and vertical lines is known as astigmatism. This aberration (astigmatism) is especially noticeable at the outer edges of the image. Figure 3-28 shows a representation of the problem. When vertical lines are brought into focus, the horizontal lines are out of focus, and when the horizontal lines are in focus, the vertical lines are out of focus.

As with most aberrations (after focus has been adjusted), the blur in the image can be reduced by using a smaller aperture. Then only the center of the lens is used to form the image.

In the modern astigmatic lenses the separation between the focus for horizontal and vertical lines is very small. Lenses corrected for astigmatism are termed anastigmatic. Anastigmatic lenses are corrected for all other lens aberrations.

*Coma.* This type of aberration is caused by the inability of a lens to bring oblique rays to a common point—and to bring them to it with equal magnification and brightness. Light rays in passing through a single lens at an oblique angle focus in the same plane, but fall at different points, rather than being superimposed. The image formed by the ray which strikes nearest the center of the lens produces the smallest and brightest point. The rays striking the lens toward the edge produce images which are increasingly larger and dimmer. The total effect is an image of a point that is smallest at its brightest end and grows larger toward the dimmest end. Because the image of a point tends to resemble that of a comet, the aberration was named coma. To understand the appearance of this type of aberration, examine the illustration in figure 3-29.

To correct or minimize coma in a compound lens, positive and negative elements of varying radii of curvature are combined in a lens system, and the size of the aperture is reduced. As yet, no lens has been made that is free of all coma and spherical aberrations. The designer must make a compromise between the two, and a residual called zoned aberration remains. Somewhere on the image plane a circle around the optical axis will appear. The task of the designer is to make this circle as narrow as possible.

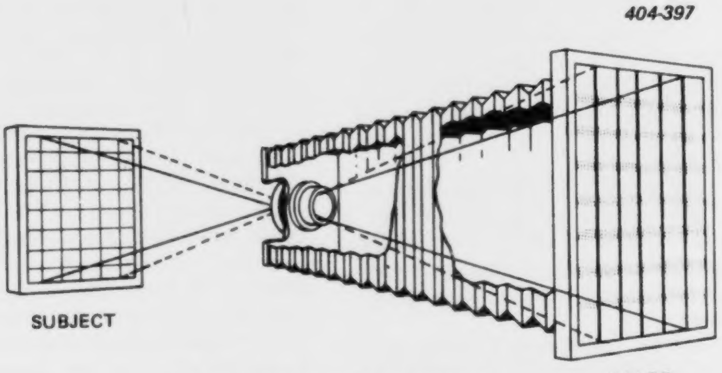
*Spherical aberration.* Spherical aberration is the term used to name the defect caused by rays that pass through the margin of the lens and come to focus either nearer to or farther from the lens than rays passing through the center of the lens. You can understand the problem better by looking at figure 3-30. Most photographic lenses are corrected for this aberration. However, a certain amount of spherical aberration is purposely left in soft-focus lenses to give the desired softness to the image. Spherical aberration is especially noticeable in short-focus, single-element lenses, where curvature of the lens is quite pronounced.

To eliminate this aberration, simple positive and negative lenses are combined in a lens system, and reduction of the aperture can also eliminate spherical aberration.

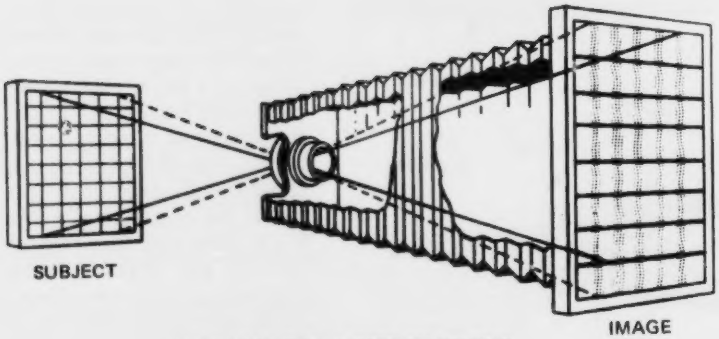
*Curvature of field.* The aberration caused by the inability of a lens to form an image of flat objects on one flat plane is called curvature of field. A lens with this type of aberration forms an image that is in focus only on a spherical surface. Observe figure 3-31, which illustrates the effect caused by a lens having curvature of field. Since the average camera has a flat focal plane, it is not possible to get the entire image in focus with a single-position focal plane.

To correct this aberration, the designer must change the curvature of the lens so it will form a sharp image on a flat focal plane. When these corrections have been made, the lens is said to have a flat field.

*Curvature of distortion.* This type of aberration causes incorrect rendering in the image of straight lines in the subject. Figure 3-32 illustrates this type of aberration. When curvature aberration is present in a lens, it is particularly prominent in that portion of the



VERTICAL LINES IN FOCUS



HORIZONTAL LINES IN FOCUS

Figure 3-28. Astigmatism.

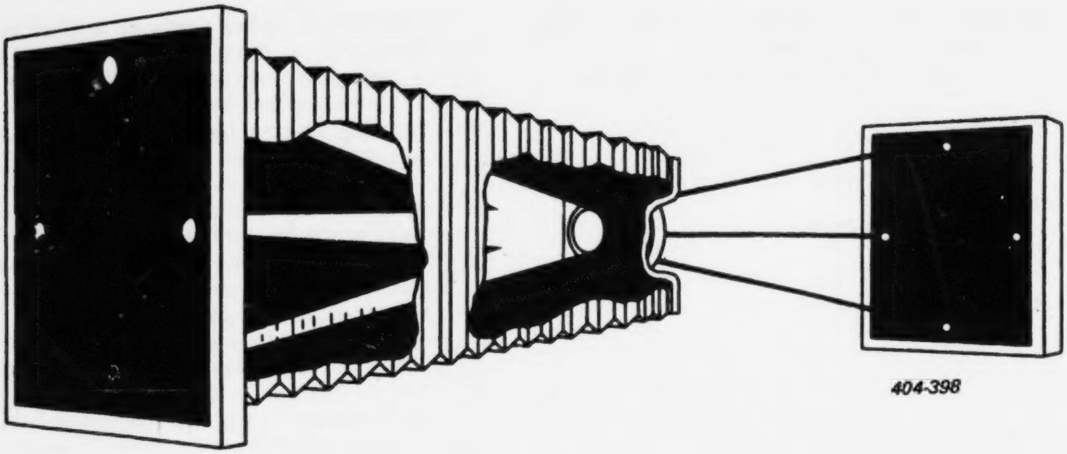


Figure 3-29. Coma.

image formed near the margins of the field of the lens.

There are two types of curvature distortion. When the lines near the margin are curved outward like the sides of a barrel, the lens has barrel distortion. When the lines near the margin are curved inward like a stuffed pincushion, the lens has pincushion distortion.

To correct for curvature distortion, place a stop (to be discussed later in this chapter) on its axis to cause distortion. The distortion caused by the stop placed in front of the lens will cause the barrel distortion to form the image outward. A stop placed behind the lens will cause the image to form inward, helping to eliminate pincushion distortion.

The correction for this aberration is a multielement lens which has a stop placed between them. By using this system, both types of curvature distortion can be corrected with satisfactory results.

*Flare*. A good lens must be corrected for the aberrations that have been described; however, these corrections alone are not sufficient. In addition to the light that produces the image, there is usually some stray or unwanted light from several sources which also falls upon the image plane. This stray light is termed "flare." Flare arises from several causes, but the most common types are classified as either mechanical flare or optical flare.

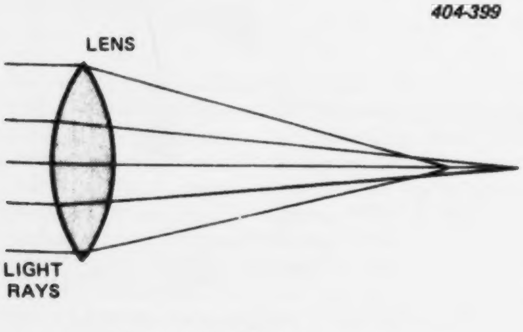


Figure 3-30. Spherical aberration.

Mechanical flare is the flare caused by reflections that occur because of reflective surfaces on the inner side of the lens barrel, the camera, or anywhere else near the lens. Normally, mechanical flare is not an inherent characteristic of the lens, but is the result of a damaged surface. Light coming from the subject reflects from such surfaces instead of being absorbed, and is reflected to the film. Such flare can be corrected by coating damaged surfaces with a nonreflective coating.

Optical flare is the flare that results from internal reflections from the glass-to-air surfaces of the lens itself. Optical flare is not classified as an aberration, and it is present to some extent in any lens that has more than one element. Generally speaking, the more complex the lens, the greater the amount of optical flare. This is because of the greater amount of glass-to-air surface.

The effects of flare are varied. Optical flare tends to cause ghost images that are not critically sharp on the focal plane. It also reduces the image contrast at the focal plane. In addition, the images are of a different size than the principal image. Mechanical flare tends to cause circular patches and a reduction in image contrast. Figure 3-33 illustrates the two different flare conditions.

**Exercises (217):**

1. Determine the lens aberration that probably resulted in the following discrepancies.
   a. A color transparency in which the blues seem to be out of focus.

b. A negative in which the images at the edge appear to be elongated.
c. Decreased subject contrast in a negative.

2. How can the effects of the following aberrations be reduced?
   a. Chromatic aberration.
   b. Astigmatism.
   c. Coma.
   d. Spherical aberration.

### 3-3. Optical Systems

There are, as discussed earlier, two broad divisions of simple lenses: the convergent or positive, which is thicker in the middle; and the divergent, or negative, which is thicker at its edges. The positive lenses cause light to converge and are called convex, while the negative lenses cause light rays to diverge and are referred to as concave.

Positive lenses, either singly or in combination, have the power of converging light rays. All lenses used in cameras to form real images are of this form. Negative lenses spread the light rays. They are capable of forming a virtual (greatly reduced) image and consequently are used as direct vision viewfinders.

The modern optical system is constructed of simple lenses in various combinations. When simple lenses are properly combined, they will aid each other in reducing the aberrations. Once a simple lens is combined into a compound lens, it then becomes one element of the compound lens.

Once the elements for a compound lens are combined, they are then placed in the mounting. The choice of mounting depends on the use of the optical system. The barrel mount and the between-the-lens shutter barrel mount are the two basic mounts used in an optical system.

The design of an optical system depends on the use. The use will determine the factors that are common in all lenses. In this section, we will discuss the terms associated with lenses, exposure computations, and different types of optical systems you may encounter as a precision photographic systems specialist.

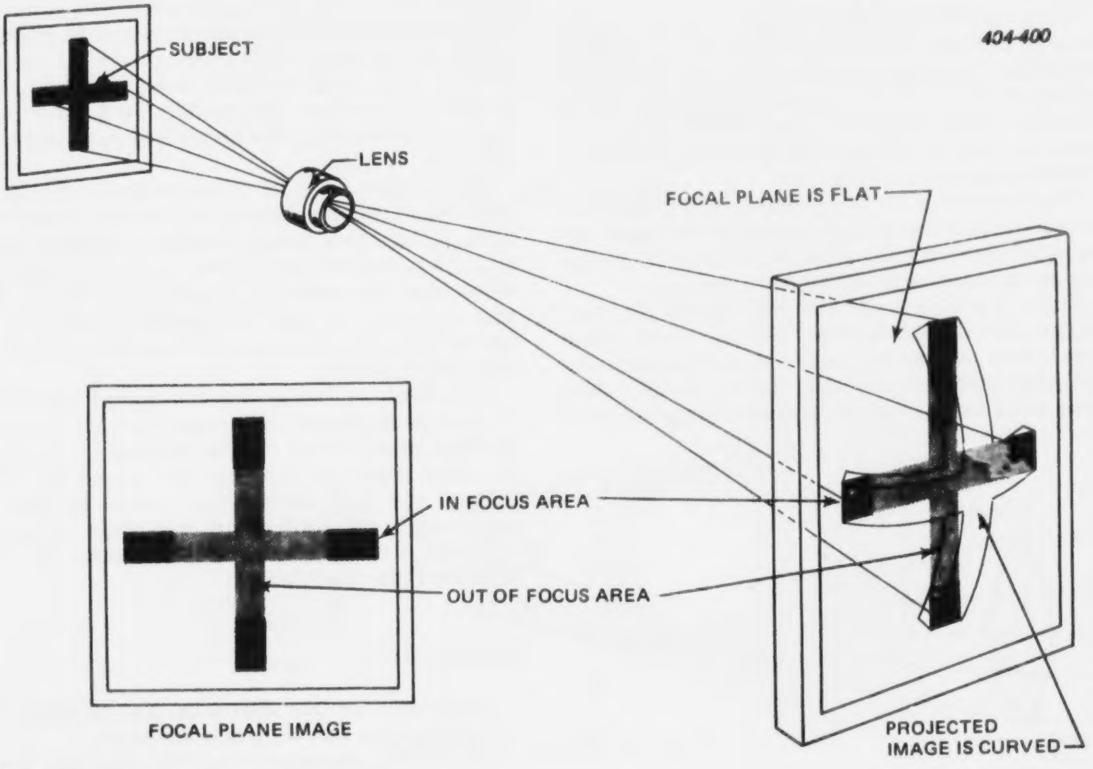


Figure 3-31. Curvature of field.

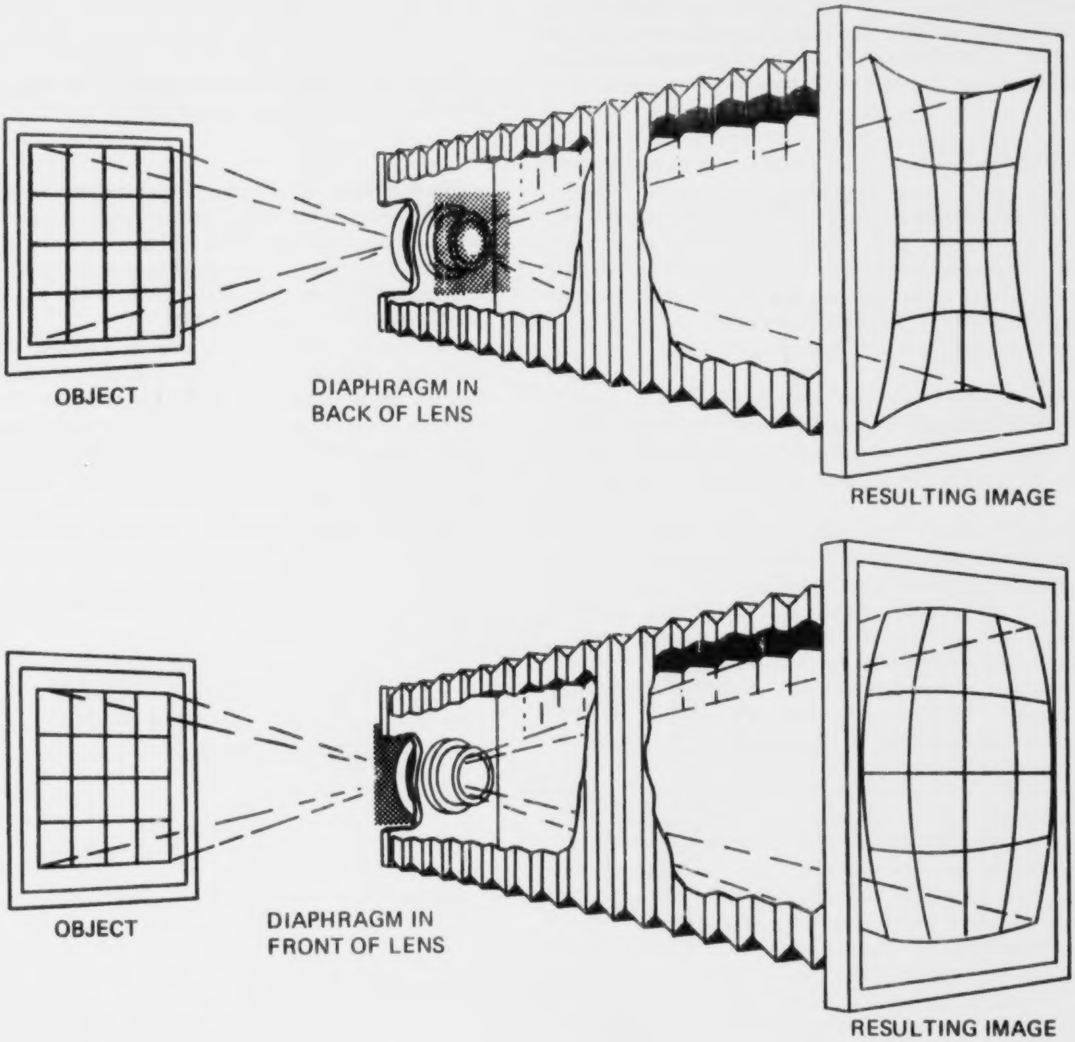


Figure 3-32. Curvature of distortion.

**218. Define resolving power, definition, and accuteness.**

**Resolving Power.** The term "resolving power" refers to the ability of an emulsion or lens to record fine detail distinguishably. In measuring resolving power, a parallel-line test chart is photographed at a great reduction in size. The lines of the test chart are separated by spaces of the same width as the lines. This separation is usually measured in lines per millimeter. Thus, if the resolving power of a lens is 100 lines per millimeter, the lens will record 100 definitely separated lines per millimeter. Most high quality lenses have a resolving power that far exceeds the resolving power of the film, but in order to realize the maximum resolution of which the film is capable, the lens should usually have at least three times the resolving power of the film.

**Definition.** The term "photographic definition" is the combined effects of resolving power and acuteness. Resolution is concerned solely with ability to record very fine detail; acuteness is concerned with sharpness or clarity of detail. Edge sharpness permits an image interpreter to determine accurately the shape and dimensions of an object. While both resolving power and acuteness are important to overall definition, a photograph can have very fine resolving power and yet not look good because acuteness is poor. On the other hand, a photograph can have high acuteness and look good even though, under magnification, it contains very little fine detail because the resolving power is not good.

**Exercises (218):**

1. Edge sharpness is another term for__________.

2. Define resolving power.

3. Resolving power is usually measured in_______ _______.

4. Photographic definition is the combined effects of__________ and__________.

**219. In a given situation, determine which lens to use for subject coverage and image size.**

**Focal Length.** The term "focal length" is defined as the distance between the optical center of the lens and the camera focal plane when the lens is focused on infinity. To understand this definition, it is essential that you fully understand the terms "optical center" and "infinity."

The optical center of a lens is a point, usually (although not always) within a lens, at which the rays of light from two different sources entering the lens are assumed to cross. The term "infinity" is not easily described, but can be defined as that distance at which parallel lines appear to converge. For example, when looking down a long straight section of railroad track, the two parallel rails

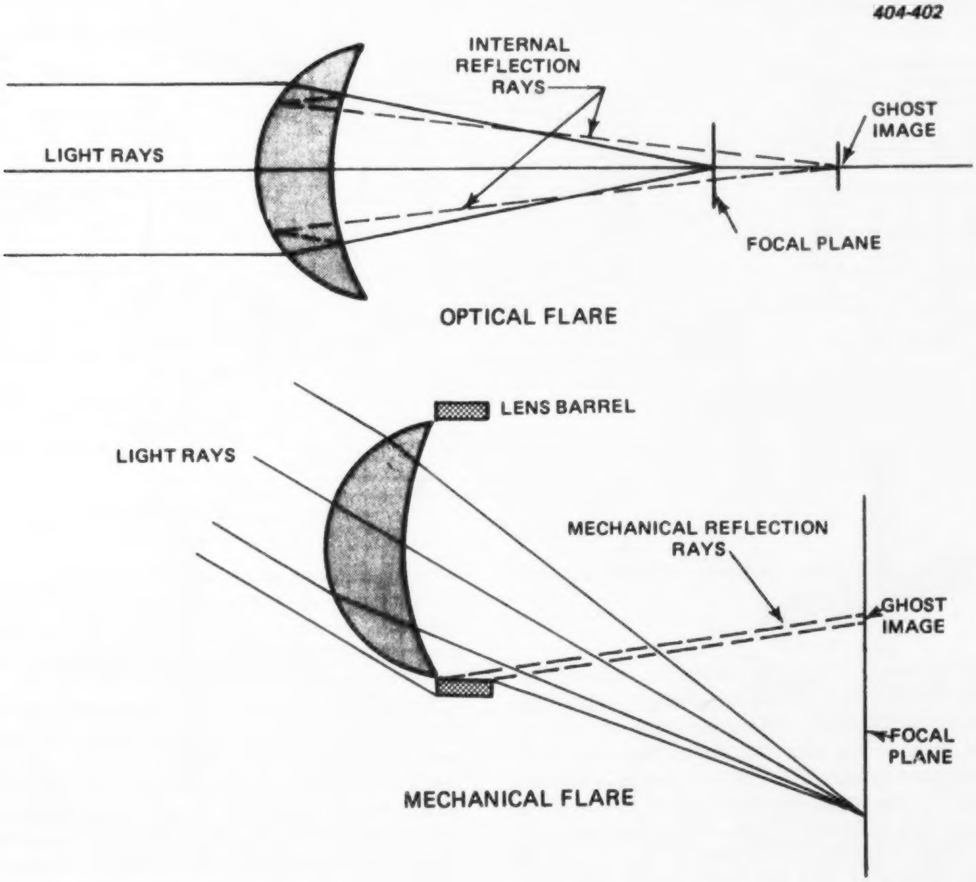


Figure 3-33. Flare.

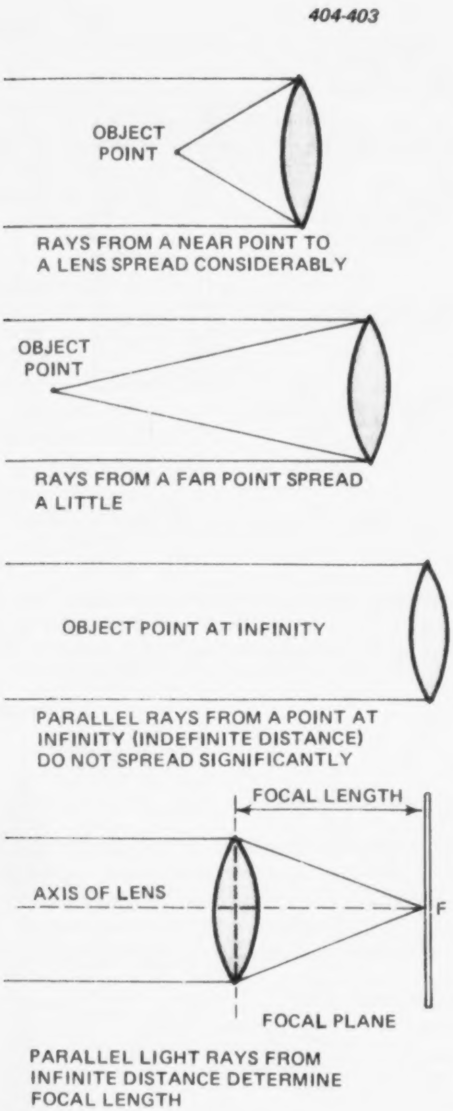

404-403
OBJECT POINT
RAYS FROM A NEAR POINT TO A LENS SPREAD CONSIDERABLY
OBJECT POINT
RAYS FROM A FAR POINT SPREAD A LITTLE
OBJECT POINT AT INFINITY
PARALLEL RAYS FROM A POINT AT INFINITY (INDEFINITE DISTANCE) DO NOT SPREAD SIGNIFICANTLY
FOCAL LENGTH
AXIS OF LENS
F
FOCAL PLANE
PARALLEL LIGHT RAYS FROM INFINITE DISTANCE DETERMINE FOCAL LENGTH

Figure 3-34. Effects of lens-to-subject distance on light.

appear to converge at a point in the distance. Then an object at that distance is said to be at infinity. Thus, when the image of an object at a comparable distance is sharply focused by a lens, the position of the lens in relation to the image is being focused at infinity.

Infinity, expressed by the symbol ∞, is a computable distance, far from the lens, which can be determined when the characteristics of the lens are known. The wave front from a point at the infinite distance appears straight in relation to the diameter of the lens. Therefore, the rays from such distance point sources are said to be parallel when entering the lens (see fig. 3-34). For all practical purposes, light rays from a very distant object, approximately 100 meters, may be considered to be parallel. If a very long focal length lens is used, 100 meters may be much less than infinity.

The manner in which the light rays are refracted by the lens determines the focal length. This refraction depends on the glass used in the elements. The formation and curvature of a lens are inherent factors that cannot be changed. However, a third factor can be changed individually in certain lenses. In some lenses, portions of the lens can be used by themselves. In others, the distance separating the lens elements can be altered. By either method, the focal length of the lens can be altered. If one of the two conditions cannot be met, the focal length is constant.

Photographic lenses are measured by their focal length, which is normally expressed in millimeters or inches. The distance is usually imprinted on the lens mounting (normally on the front surface of the barrel).

A knowledge of focal length, as related to photographic lenses, is important because the focal length determines the size of the image produced by a given lens at a given lens-to-subject distance.

**Focal Length and Image Size.** A lens that has a long focal length produces a larger image on the focal plane than one with a short focal length, assuming both are used at the same lens-to-subject distance. In effect, the long focal length lens brings the subject closer to the camera without changing the camera-to-subject distance. For example, a man 1.8 meters (6 feet) tall stands at a distance of 7.6 meters (25 feet) from the camera, one camera equipped with a 152-mm lens, one with a 305-mm lens, and one with a 610-mm lens. The 152-mm lens produces a 38-mm image of the man on the focal plane, while the 305-mm lens produces a 76-mm image. The 610-mm lens produces a 152-mm image, twice as large as the one with the 305-mm lens and four times as large as the one with the 152-mm lens. The longer the focal length of the lens, the larger the image size of a given objective from a given lens-to-subject distance.

**Focal Length and Subject Coverage.** Focal length and subject coverage go together—just as do focal length and image size. Image size increases with increased focal length; coverage decreases with increased focal length. Coverage is the amount of subject matter included in a given format from a given lens-to-subject distance. With three cameras of three different focal lengths at the same distance from the same subject, the camera with the shortest focal length includes the most subject area, while the camera with the longest focal length includes the least. Both image size and coverage in relation to focal length can be seen in figure 3-35, which shows the same subject taken from the same viewpoint with three different focal length lenses. The effect of focal length on image size and coverage must be thoroughly understood if a lens is to be used to its greatest advantage. Be sure you understand the principles set forth pictorially in figure 3-35.

**Exercises (219):**

1. If you want maximum coverage of a scene and you have two cameras, one with a 2-inch focal length and one with a 3-inch focal length, which would you use?

2. If you were using the same cameras as in exercise 1, which camera would you use for maximum image size of a small object?

**220. Use lens speed equations to compare the speed of different lenses.**

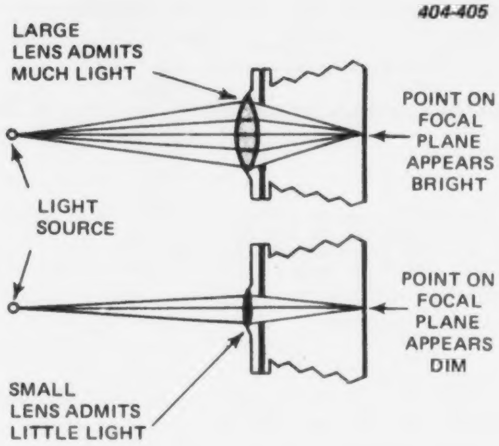

404-405
LARGE LENS ADMITS MUCH LIGHT
POINT ON FOCAL PLANE APPEARS BRIGHT
LIGHT SOURCE
POINT ON FOCAL PLANE APPEARS DIM
SMALL LENS ADMITS LITTLE LIGHT

Figure 3-36. Effects of diaphragm opening.

**Lens Speed.** One major characteristic of a lens is its speed. The term "lens speed" refers to the maximum aperture diameter (smallest f/number) of a lens—the maximum amount of light that a lens allows to pass to the focal plane to form the image. Lens speed, usually indicated by a numerical value

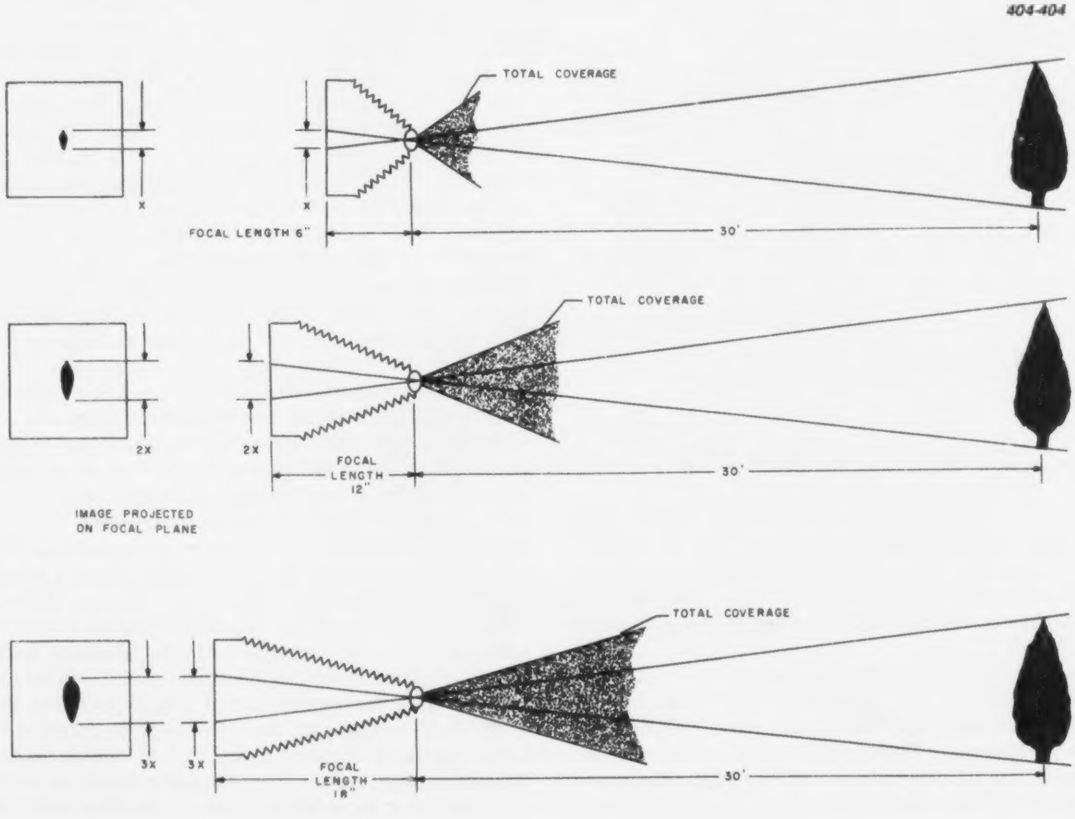


Figure 3-35. Image size and coverage as compared to focal length.

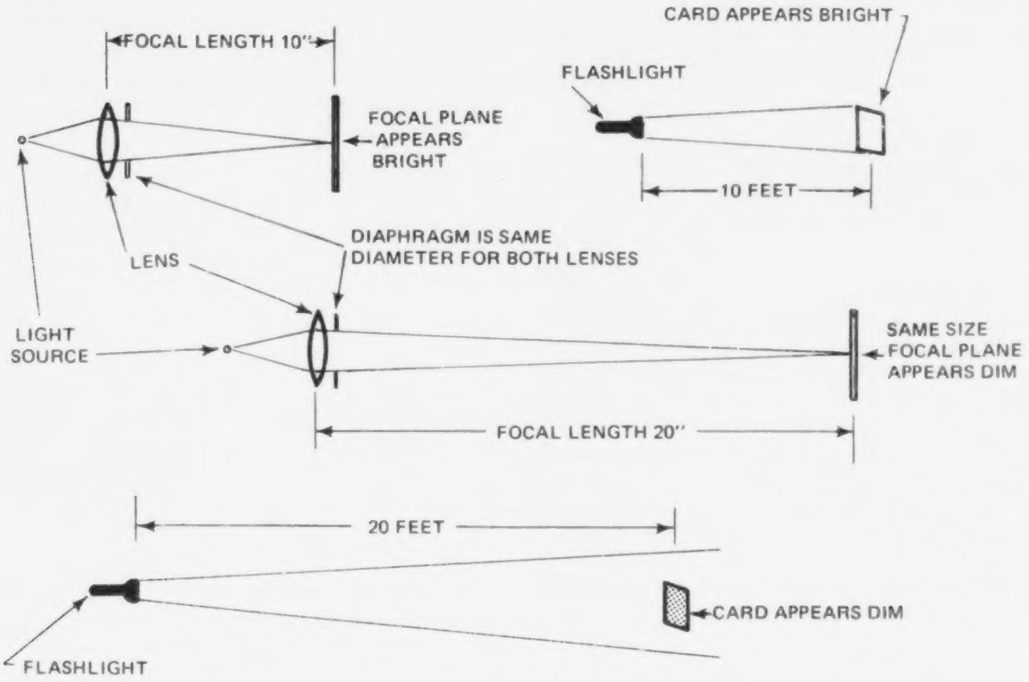


Figure 3-37. Effects of focal length on image brightness.

termed an "f/number" is dependent upon two factors and their relationship. These factors are the maximum aperture diameter of the lens and the focal length of the lens. The relationship between focal length (FL), diameter (D), and lens speed is expressed as:

$$\text{Lens speed} = \frac{FL}{\text{maximum } D}$$

Look at figure 3-36. With the focal length remaining constant, a lens having a larger aperture diameter allows more light to reach the focal plane than does a lens having a smaller aperture diameter. Therefore, the lens with the larger aperture diameter is capable of producing a brighter image than the one with the smaller aperture diameter and is termed "faster." Conversely, the lens with the smaller aperture diameter is termed "slower."

Now observe figure 3-37. If the aperture diameter remains constant, the focal length affects the image brightness. Since the light has less distance to travel from the lens to the focal plane in the short focal length lens, the image is brighter and the lens is considered to be faster. Conversely, with a lens having the same aperture diameter but a longer focal length, the light must travel farther from the lens to the focal plane, the image is dimmer, and the lens is considered slower. The terms "fast" and "slow" are relative, and there is no definite dividing point between the two. The effect of focal length on image brightness can easily be compared to the shining of a flashlight on a white card. The farther the distance from the flashlight to the card, the dimmer the light becomes, or the less illumination the card receives.

To summarize, for a given focal length the speed of a lens varies directly as the diameter of the aperture varies—the larger the aperture diameter, the faster the lens and the brighter the image. For a given aperture diameter, speed varies inversely as the focal length of the lens varies—the longer the focal length of the lens, the slower the lens and the dimmer the image.

To fully realize the significance of variations in focal length on lens speed, you should understand the inverse-square law, which states that the illumination on a surface by a pointed light source varies inversely as the square of the distance from the source:

$$\text{Intensity} = \frac{1}{\text{distance}^2}$$

The intensity of the illumination depends on the area of the surface over which the amount of light is spread. This law applies to light rays diverging from a point source, not from light rays being generated from sources such as a fluorescent tube or an optical system involving mirrors or lenses (a searchlight). Neither does it apply if a large light source is used relatively close to the surface.

For an example of how this law works, see figure 3-38. If you place a card 305 mm (1 foot) from a light source, the light striking the card is of a certain intensity. If the card is moved 610 mm (2 feet) away, the intensity decreases with the square of the distance ($2^2$, or 4 times) and is one-fourth as bright. If the card is moved 1.2 meters (4 feet) away, the intensity drops to one-sixteenth of the original intensity. In photographic work, the lens acts as the light source for the film.

Since speed of a lens is the ratio of maximum aperture diameter to focal length, many combinations can provide a specific lens speed. For instance, a lens with a maximum diameter of 25.4 mm and a focal length of 50.8 mm would have a speed of f/2, or lens speed = 50.8 (focal length) divided by 25.4 (maximum diameter). A lens 152 mm in diameter with a 305-mm focal length would also have a speed of f/2.

Look at figure 3-39 and make sure you fully understand the principle. Lens B has four times the area of lens A; consequently, it projects four times as much light toward the focal plane. But the light must travel twice the distance to reach the focal plane of camera B. According to the inverse-square law, the increase in distance traveled decreases the intensity to one-fourth; therefore the light reaching the focal plane of camera B is of the same intensity as the light reaching the focal plane of camera A.

**Exercises (220):**

Using the lens speed formula, determine which lens would have the fastest rating.

| | *Lens A* | | *Lens B* | |
|---|---|---|---|---|
| | *FL* | *D* | *FL* | *D* |
| 1._____ | 152mm ( 6") | 25.4mm (1") | 228mm ( 9") | 35.5mm (1.4") |
| 2._____ | 457mm (18") | 50.8mm (2") | 355mm (14") | 152 mm (6") |
| 3._____ | 76mm ( 3") | 50.8mm (2") | 127mm ( 5") | 76 mm (3") |
| 4 _____ | 228mm ( 9") | 76 mm (3") | 152mm ( 6") | 68.5mm (2.7") |
| 5._____ | 305mm (12") | 76 mm (3") | 254mm (10") | 63.5mm (2.5") |
| 6._____ | 203mm ( 8") | 50.8mm (2") | 228mm ( 9") | 63.5mm (2.5") |

**221. Given a situation, use the f/stop equation to determine exposure time.**

Now that you understand the effects of lens speed on the intensity of light reaching the focal plane of

404-407

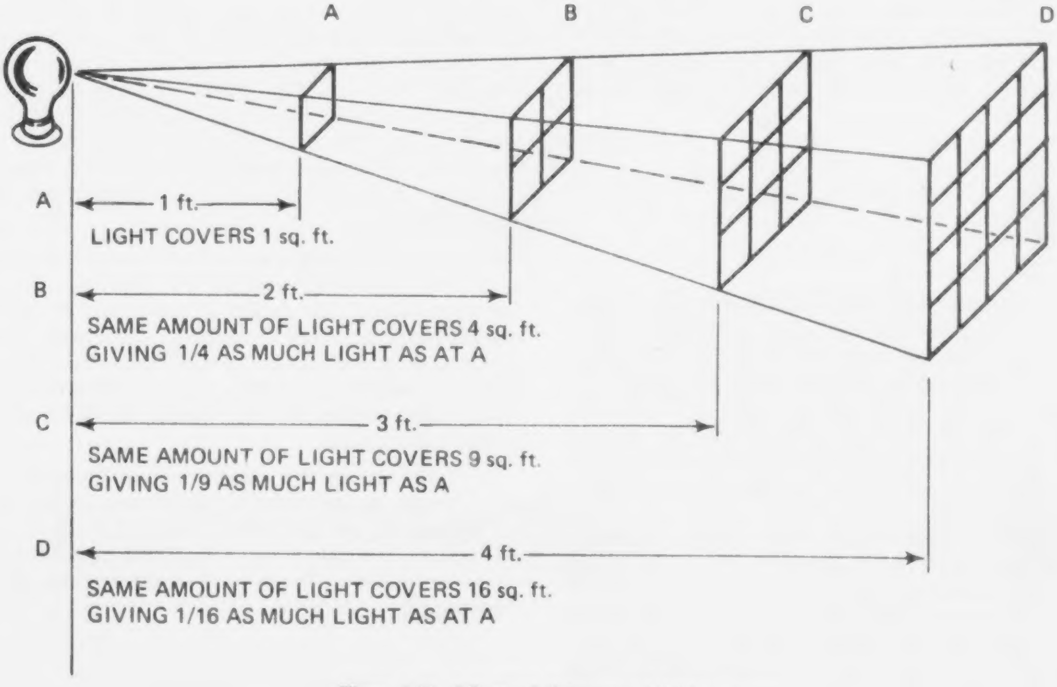

A
B
C
D
A
1 ft.
LIGHT COVERS 1 sq. ft.
B
2 ft.
SAME AMOUNT OF LIGHT COVERS 4 sq. ft.
GIVING 1/4 AS MUCH LIGHT AS AT A
C
3 ft.
SAME AMOUNT OF LIGHT COVERS 9 sq. ft.
GIVING 1/9 AS MUCH LIGHT AS A
D
4 ft.
SAME AMOUNT OF LIGHT COVERS 16 sq. ft.
GIVING 1/16 AS MUCH LIGHT AS AT A

Figure 3-38. Effects of distance on brightness.

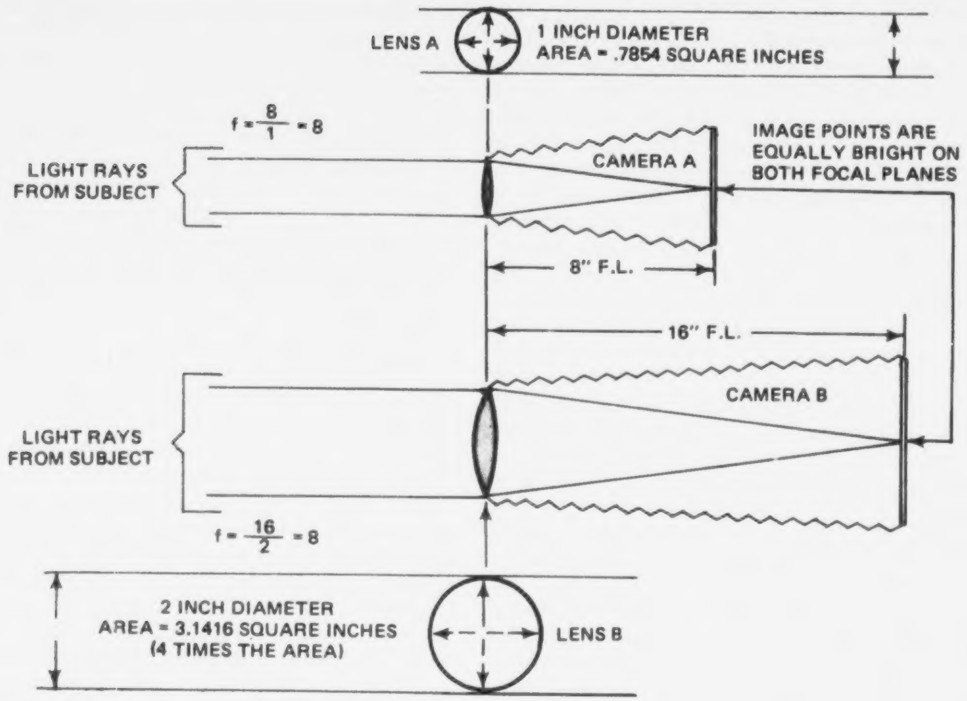


Figure 3-39. How two lenses can have the same f value.

a camera, let us see how the f numbers of a lens are related to determining exposure time.

**Exposure Control.** The method used to control exposure in an optical system employs two mechanical devices—a diaphragm and a shutter. Both of these devices are variable, one controlling intensity, the other time. Correctly setting the diaphragm (f/stop) and shutter (speed), one in relation to the other, is necessary to produce a given effect—a correct exposure of the film.

**Diaphragm.** The diaphragm is a device used to vary the diameter of the opening which passes the light transmitted through the lens to the film. It consists of a number of thin metal or composition sheets attached to a ring in such a manner that they form a circular opening. Rotating the ring to which the diaphragm sheets are attached causes them to vary the size of the opening through which the light is transmitted. The diaphragm is usually mounted inside the barrel mount between the elements of the lens.

As mentioned earlier, the speed of a lens is determined by dividing the focal length by the effective lens diameter. This gives you the wide open speed of the lens. So by using the variable diaphragm, you can alter the speed of a fixed focal length lens by using the diaphragm to change the effective lens diameter.

**F/stop System.** Starting with the unity of 1, the f/numbers progress in sequence according to the square root of 2 (1.4142) in order that the intensity be reduced by exactly one-half for each successive opening. Then the series of f/numbers is engraved on the lens barrel or shutter adjacent to an aperture indicator. This indicator is coupled to the diaphragm ring for convenience in setting the diaphragm at the desired aperture. Each f/number has been mathematically determined so that the value of light transmitted at any given f/number is exactly one-half the intensity of light transmitted by the next larger diaphragm opening. As the aperture opening indicator is moved from one f/number to the next, the relative exposure will either be doubled or reduced by one-half, depending on the direction the indicator is moved.

The series of numbers on the diaphragm scale have the following sequence and are called full f/stops: 1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32, 45, 64, and 90. It is important to remember that as the numerical value of the f/number increases, the amount of transmitted light decreases. For example, f/16 transmits exactly one-half as much light as f/11 for the same period of time.

Unfortunately, all f/numbers indicated on a lens are not always full stops. The first number will depend on the construction of the lens. The wide open f/number for a particular lens will be the first number. This number could be half-way, three-quarters, or any arbitrary point between full stops. In such cases, it is customary for the second f/number marked on the lens to indicate a full stop. For example, if a lens has a maximum aperture of f/4.5, the scale would be marked as follows: 4.5, 5.6, 6.3, 8, 11, 16, and 32. Lenses marked in this manner frequently use a half or intermediate stop as the third indicated f/number, such as the 6.3 in the series above.

It should be noted that throughout the series of numbers the relative amount of light transmitted varies inversely with their values; that is, f/8 transmits only one-fourth as much light as f/4, instead of one-half. The difference in intensities can be quickly determined by squaring the two f/numbers and dividing one product by the other. For example: $4^2/8^2 = 16/64 = 1/4$, or f/8 transmits 1/4 as much light as f/4. To compensate for the different openings of the diaphragm, we can increase or decrease the exposure time to get the same exposure. For example, if the diaphragm is changed from f/4 to f/8, one-fourth the light intensity is then transmitted. If the exposure at f/4 was 1 second, then the exposure time for f/8 would have to be increased by a factor of 4, or 4 seconds.

**Exercises (221):**

1. You have a camera lens set at f/8 and 1 second exposure time. You change it to f/16. What is the new exposure time?

2. Changing an f/stop from f/4 to f/16 increases the exposure time by what amount?

**222. Given a situation, use the hyperfocal distance equation to determine hyperfocal distance.**

**Hyperfocal Distance.** The hyperfocal distance of a lens is defined as the distance from the optical center of the lens to the nearest point in acceptably sharp focus when the camera is focused on infinity at any given f/number (see fig. 3-40). The lens, however, does not focus the rays into a point on the focal plane. The rays are focused on the focal plane as small circles called circles of confusion. The permissible diameter of the circle of confusion for most types of photography is 0.1016 mm (1/250 inch). However, if only contact prints are to be made, a circle of confusion as large as 0.254 mm (1/100 inch) may be allowed. Normally, the maximum circle of confusion permissible in negatives made with miniature cameras is 0.0254 mm (1/1000 inch). At this diameter the circle of confusion will appear as a

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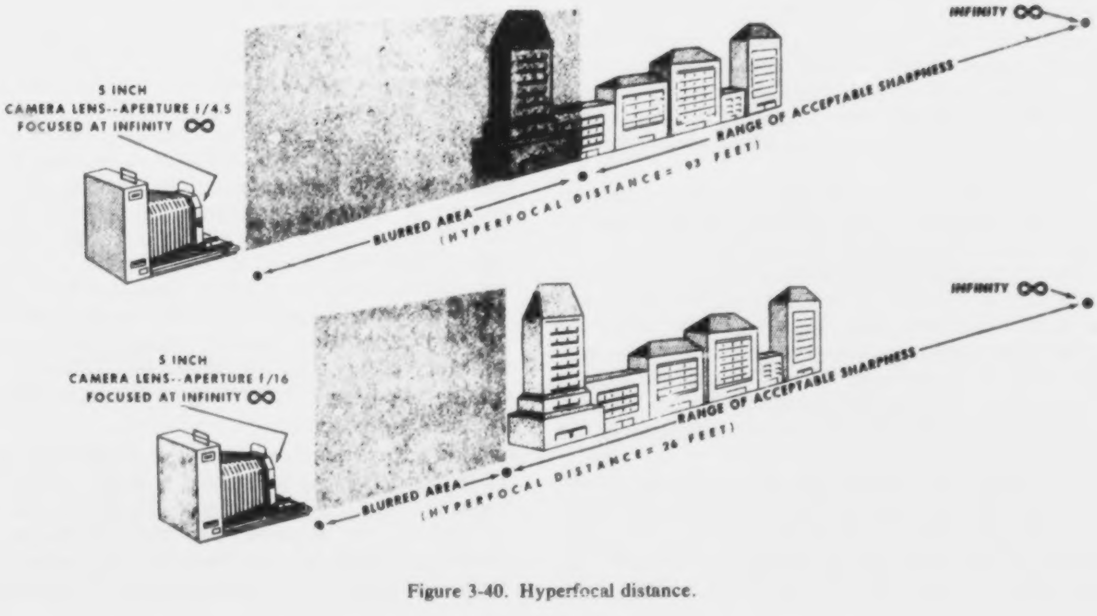

INFINITY ∞
5 INCH
CAMERA LENS--APERTURE f/4.5
FOCUSED AT INFINITY ∞
RANGE OF ACCEPTABLE SHARPNESS
BLURRED AREA
(HYPERFOCAL DISTANCE= 93 FEET)
INFINITY ∞
5 INCH
CAMERA LENS--APERTURE f/16
FOCUSED AT INFINITY ∞
RANGE OF ACCEPTABLE SHARPNESS
BLURRED AREA
(HYPERFOCAL DISTANCE= 26 FEET)

Figure 3-40. Hyperfocal distance.

point from normal viewing distance (approximately 254 mm, or 10 inches). If the circle is larger in diameter, the eye usually distinguishes it as a circle instead of a point, and the photograph appears blurred or out of focus.

When a lens is critically focused at infinity on an object, everything in a vertical plane at that point forms an image composed of the smallest circles of confusion that the lens can produce. Things in front of this plane of critical sharpness will register on the focal plane in ever-increasing circles of confusion until the image begins to blur.

The *HFD* varies with the focal length of the lens and the f/stop at which the diaphragm is set. The shorter the focal length and the smaller the aperture, the shorter the hyperfocal distance. The formula for finding *HFD* is:

$$HFD = \frac{FL^2}{f \times C}$$

where

$HFD$ = hyperfocal distance
$FL$ = focal length
$f$ = aperture or f/stop
$C$ = circle of confusion

The results can be either millimeters or inches if all factors are converted. *Example:* Find the hyperfocal distance of a lens that has a focal length of 254 mm (10 inches) when using f/4.5 and a circle of confusion of 0.1016 mm (1/250 inch).

A. Solving for meters:

$$HFD = \frac{FL^2}{f \times C}$$

where

$FL^2 = 254\ \text{mm}^2$
$f = 4.5$
$C = 0.1016\ \text{mm}$

then

$$HFD = \frac{254 \times 254}{4.5 \times 0.1016} = \frac{64516}{0.4572} = 141111.1\ \text{mm} =$$

$$141.111\ \text{meters}$$

B. Solving for feet:

$$HFD = \frac{FL^2}{f \times C}$$

where

$FL^2 = 10^2$
$f = 4.5$
$C = 0.004$

then

$$HFD = \frac{10 \times 10}{4.5 \times 0.004} = \frac{100}{.018} = 5555\ \text{inches} = 463\ \text{feet}$$

Therefore, the hyperfocal distance for the above examples is 141.11 meters, or 463 feet. If solving for *HFD* using inches only, a direct solution in feet can be obtained by using the following formula:

$$HFD = \frac{FL^2}{f \times C \times 12}$$

Therefore, 12 is the conversion factor.

When the lens is focused at infinity, the nearest object acceptably sharp is 463 feet from the lens, that is, sufficiently sharp for an f/number of 4.5 and a circle of confusion of $^1/_{250}$ inch.

The hyperfocal distance is needed to utilize the maximum depth of the field of lens. In order to find the depth of field, the hyperfocal distance must be determined first.

**Exercises (222):**

1. Assume that you are using a camera with a focal length of 6 inches and an aperture of 2.8. What is the hyperfocal distance if the circle of confusion is $^1/_{1250}$?

2. Using the same camera as in exercise 1, with everything the same except that the aperture is changed to f/2, what is the hyperfocal distance?

**223. Give a situation, use the depth-of-field equation to determine the depth of field.**

**Depth of Field.** Depth of field is the range of distances on each side of the plane focused upon which are in adequate focus. When a lens is focused at infinity, the hyperfocal distance of that lens is defined as the near limit of the depth of field, while infinity is the far distance. When the lens is focused on the *HFD* (463 feet in the preceding discussion), the depth of field is from exactly half that distance to infinity. Figure 3-41 shows a typical depth of field of a lens.

The depth of field of a lens is controlled by, and all computations are based upon, the distance focused upon and the hyperfocal distance. Consequently, there are four factors that control depth of field, and they are as follows:

- Focal length of lens.
- Size of the circle of confusion.
- f/number used.
- Distance from the lens to the object being focused.

A short focal length lens has a greater depth of field than a long focal length lens. Hence, the shorter the focal length of the lens used, the greater the depth of field.

Depth of field increases as the lens opening (aperture) is decreased, because the size of the cones of light decreases in proportion to the aperture, as shown in figure 3-42.

When the lens is focused on a close object, the depth of field is small; and when the lens is focused

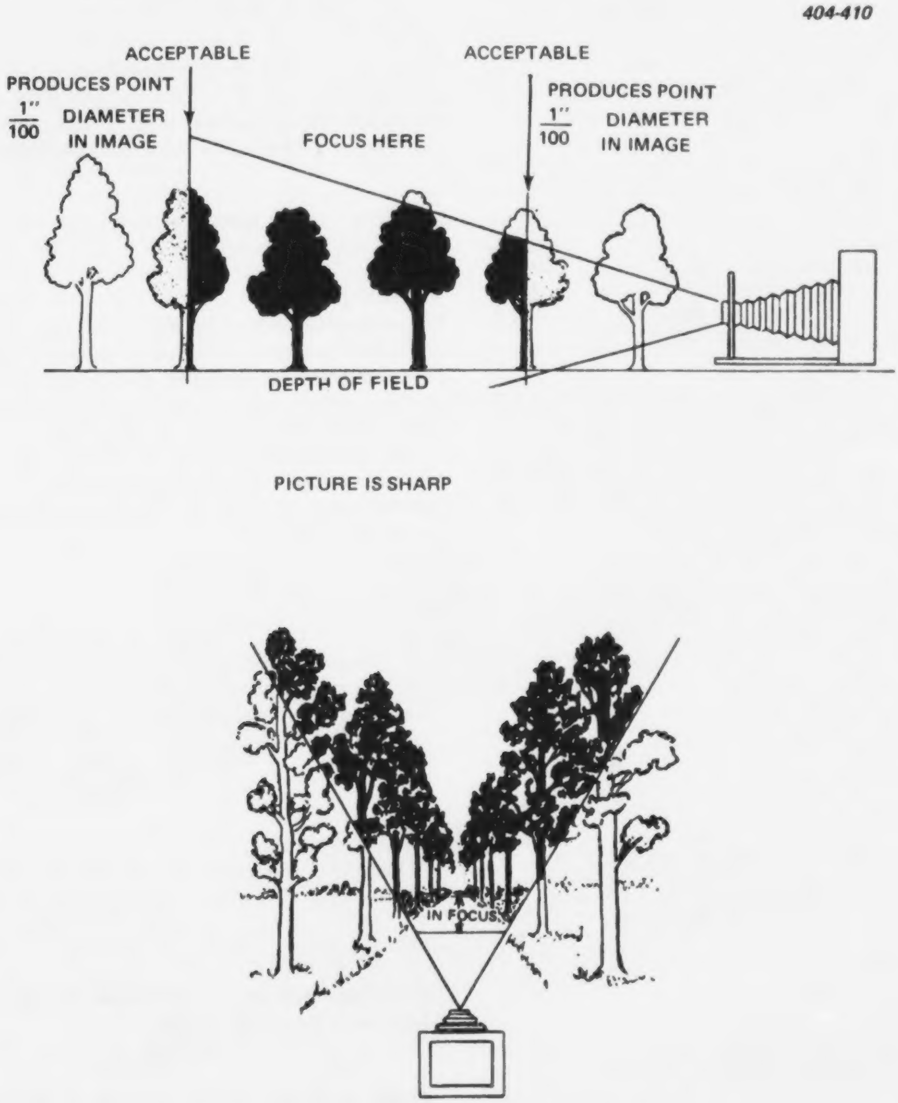


Figure 3-41. Depth of field.

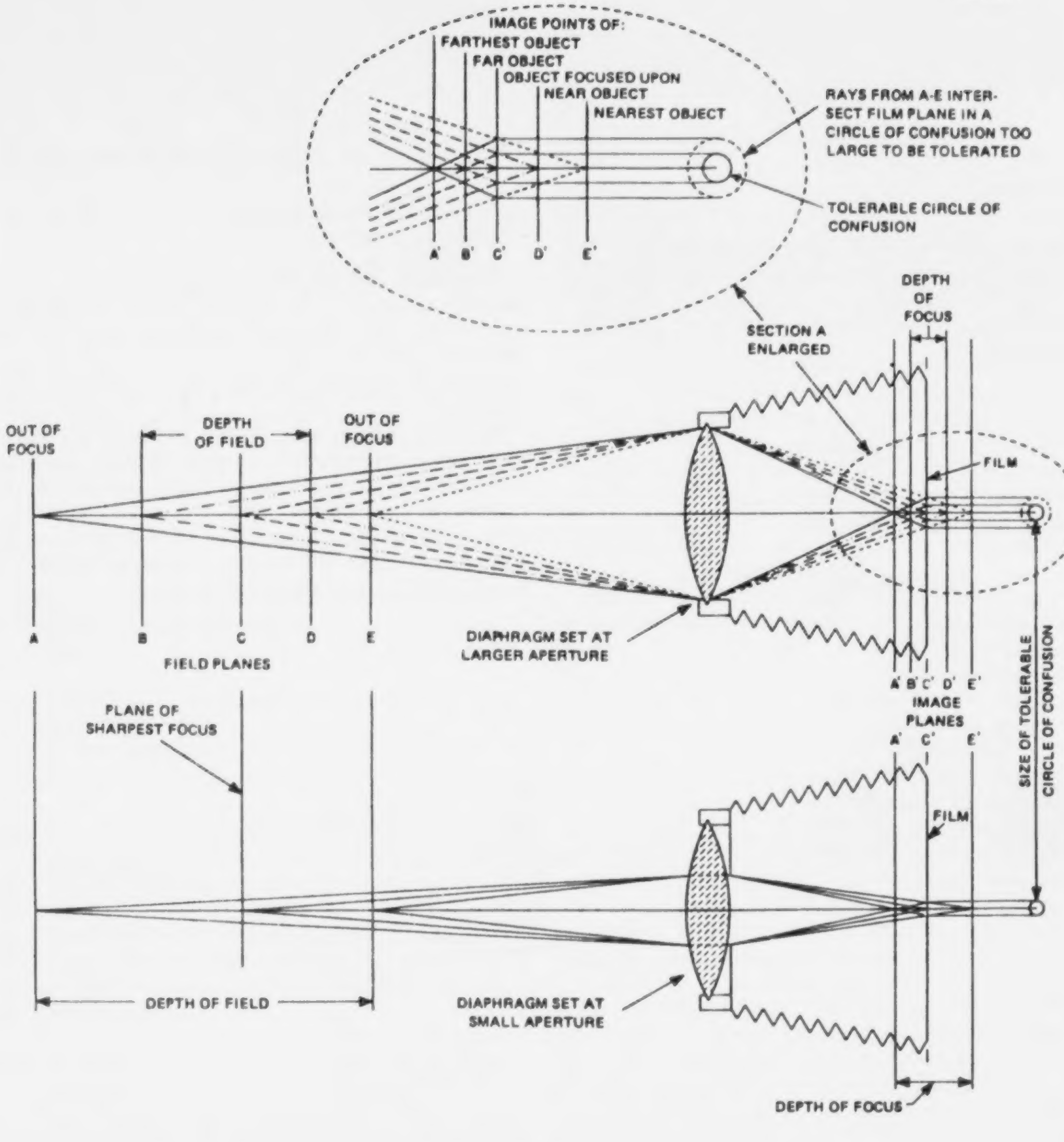


Figure 3-42. Effects of diaphragm opening on depth of field.

on an object farther away, the depth of field increases. (See fig. 3-43.)

Figure 3-43 also shows that if the photographer can be permitted a larger circle of confusion, all other factors remaining constant, the depth of field is thereby increased.

If it is necessary to figure out the depth of field for a particular lens, you can use the following formulas:

The distance to the nearest plane that is acceptably sharp (near distance) is:

$$ND = \frac{H \times D}{H + D}$$

The distance to the farthest plane that is usably sharp is:

$$FD = \frac{H \times D}{H - D}$$

where

$ND$ = Near distance
$H$ = Hyperfocal distance
$D$ = Distance focused on
$FD$ = Far distance where $H$ and $D$ are equal to the same values

For example: What is the depth of field of a 10-inch focal length lens when focused on an object 100 feet from the lens using an f/stop of 4.5? (NOTE: The *HFD* was found to be 463 feet in the previous discussion).

$$ND = \frac{H \times D}{H + D}$$

$$ND = \frac{463 \times 100}{463 + 100} = \frac{46300}{563}$$

$$ND = 82 \text{ feet}$$

Thus, the near distance in sharp focus is 82 feet from the lens.

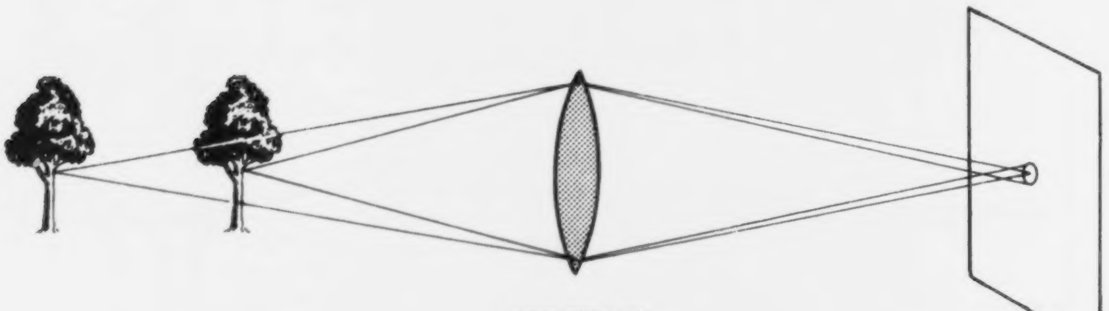
$$FD = \frac{H \times D}{H - D}$$

$$FD = \frac{463 \times 100}{463 - 100} = \frac{46300}{363}$$

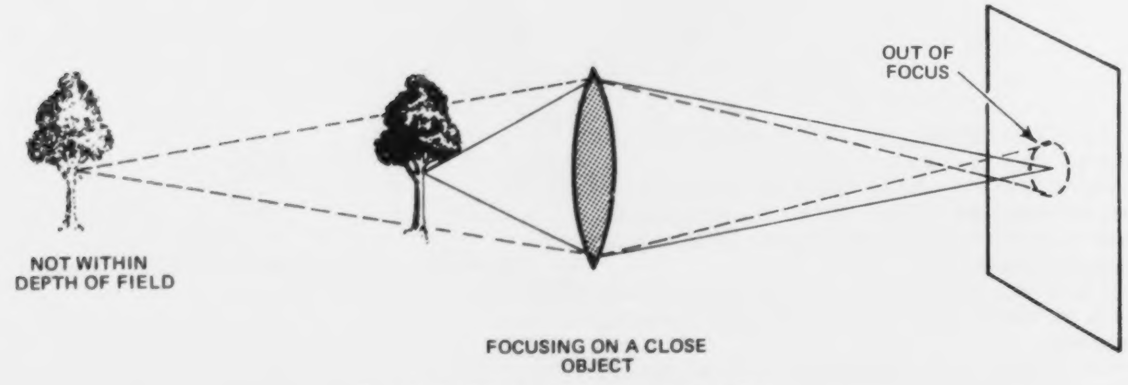
$$FD = 127 \text{ feet}$$

Therefore, the far distance in sharp focus is 127 feet. Consequently, the depth of field in this problem equals the near distance subtracted from the far distance, or 127 − 82 = 45 feet. So, all objects between 82 feet and 127 feet are acceptably sharp in focus.

Modern rollfilm and 35 mm still cameras have, for your convenience, a depth of field scale incorporated with the footage scale marked on the camera or lens barrel. With this scale, you need only to focus the camera and then read from the scale the nearest and farthest distances which will be in focus for any given f/stop.



FOCUSING ON DISTANT OBJECT



FOCUSING ON A CLOSE OBJECT

Figure 3-43. Effects of distance on depth of field.

In conclusion, the two formulas governing depth of field serve for all distances less than infinity. When the lens is focused on infinity, the *HFD* is the nearest point in sharp focus and there is no known limit for the far point.

**Exercises (223):**

1. If you use a camera with a 3-inch focal length and you focus on an object 100 feet away using an f/stop of f/2.8 and a hyperfocal distance of 335 feet, what is the depth of field?

2. Using the same camera as in exercise 1 and the same f/stop and hyperfocal distance, what is the depth of field if you focus on an object 50 feet from the lens?

### 224. Given a situation, determine the new shutter speed for relative exposure values.

As we previously mentioned in this section, exposure depends on the lens speed and the amount of time the film receives light. To correctly control the exposure time, a shutter is used in the optical system.

**Shutter.** The shutter, in conjunction with the diaphragm, forms the mechanism which exercises complete control over exposure. Its most important function is to limit the amount of time during which light is permitted to pass through the lens and act on the film. The two types of shutters commonly used on still cameras are the focal plane and between-the-lens types.

*Between-the-lens shutter.* The between-the-lens shutter employs a number of thin metal, overlapping blades arranged perpendicular to the axis of the lens in such a manner that they prevent the passage of light through the lens to the film. The blades of this type of shutter are usually located between or near the lens elements, as close as practical to the leaves of the diaphragm. It is common practice to enclose the diaphragm and shutter in the same barrel housing. Through an ingenious system of gears, levers, cams, and springs, the shutter blades may be made to spring open and allow light to reach the film. Then after a preset interval of time has elapsed, the blades spring shut, shutting off the light again.

*Focal plane shutter.* The focal plane shutter is located just forward of the focal plane of the camera. Because of the location of the focal plane shutter, it is larger than a between-the-lens shutter for the same size camera. The light-controlling portion of the shutter is called the shutter curtain. The shutter curtain is made from either a lightproof ruberized cloth or very thin metal. The size of the curtain exceeds the size of the camera format, since, when the shutter is closed, it must cover the entire format area.

In miniature cameras the shutter consists of two curtains mounted on spring-tension rollers. When the camera shutter is released, the spring tension on the rollers pulls the curtain across the entire format area. This action allows the film to be exposed until the exposure time delay action releases the second curtain to close the slit. The length of exposure is controlled by the time delay action and the velocity of the second curtain travel. The velocity of travel is controlled by an adjustable retard assembly that varies the spring tension on the curtain drive spring.

There are two basic types of focal plane shutters. One type contains a long curtain with several different-sized openings separated by a section of solid curtain large enough to cover the entire format area. The second type uses two curtains, which gives the effect of a variable width. The slit width is then varied by the selected shutter speed.

**Shutter Speeds.** The range of intervals or shutter speeds available on the modern between-the-lens shutter is usually, B, 1, ½, ¼, ⅛, $^1/_{15}$, $^1/_{30}$, $^1/_{60}$, $^1/_{125}$, $^1/_{250}$, and $^1/_{500}$ second. In addition to a given range of speeds, some shutters are designed so they can be opened for an indefinite period of time. At a setting marked "T" (time), the shutter opens at the first pressure on the release and stays open until the release is pressed again. At the setting marked "B" (bulb), pressure on the release opens the shutter, but it closes again as soon as the pressure is released. Frequently, on the more expensive shutters, a higher speed of $^1/_{750}$ to $^1/_{1000}$ second is available. The focal plane shutters on modern cameras have shutter speeds of B, 1, ½, ¼, ⅛, $^1/_{15}$, $^1/_{30}$, $^1/_{60}$, $^1/_{125}$, $^1/_{250}$, $^1/_{500}$, and $^1/_{1000}$ second.

The interval during which it is desired for a shutter to remain open is selected by moving a dial or lever to that particular setting on a speed scale. Tripping the shutter causes the shutter blades or curtains to open for the selected interval and then spring shut. It is important to note that shutter speeds are available only as marked on the shutter housing.

**Relative Exposure Values.** The relationship between shutter speed and f/stop and their effect on exposure must be clearly understood. The basic exposure can be modified by changing either the f/stop or the shutter speed, or both. For example, when it is desired to increase exposure, the diaphragm may be opened by changing the f/stop from f/16 to f/11 or f/8, etc.; or the shutter speed may be reduced from $^1/_{250}$ to $^1/_{125}$ or $^1/_{60}$ second, etc.; or both may be changed. The reverse is true to maintain the same relative exposure as given by the basic exposure when a different shutter speed or diaphragm setting is required. In this case, both settings must be changed to a new combination that produces the same amount of exposure. For example, if the shutter speed of 1/125 is too slow to stop motion, the shutter may be set at 1/250 and the diaphragm opened from f/16 to f/11 or f/8 at 1/500, etc.

The same relationship exists between shutter speeds and f/stops. If you remember, if you change the f/number one stop, you will either double the exposure or cut the exposure in half. On a shutter, the speeds are also set for exposure based on the same ratio as lens speed. If the shutter speed is changed one speed, the exposure will be doubled or cut in half. For example, a shutter speed changed from ½ second to ¼ second will only give one-half the time of the original setting, as will going from 1/60 to 1/30 double the exposure time.

**Exercises (224):**

1. If you have a between-the-lens shutter exposure set for f/11 at 1/30 second and change the f/stop to f/22, what would the new shutter speed setting be to maintain the original exposure?

2. If f/16 is an exposure setting of a camera with the shutter speed of 1/125 second, what would be the new shutter speeds to produce the same exposure for the following f/stops?
   a. f/22 ____________
   b. f/11 ____________
   c. f/8 ____________

## 3-4. Filter Characteristics

Filters are used to control the quality and intensity of the light that strikes the focal plane of the camera. By using filters, you can change the relative contrast between colors. Also, in black-and-white photography, you can intensify or subdue the effect of color, or eliminate the effect of a color completely. Only through a thorough understanding of the principles of filters can you achieve the maximum quality in photographs.

**225. Identify the color of light transmitted by given filters, and state the limitations and effects of using filters.**

**Filter Principles.** When the term "filter" is used in photographic discussion, it usually refers to a transparent colored medium employed to regulate either the color or the intensity of light reaching the film. The color of the filter will determine the color of light that reaches the film. The colorless or neutral density filte regulates only the intensity of the light.

As discussed earlier, light from the electromagnetic spectrum is broken down into colors according to their wavelengths. These colors reflect their own color and absorb other colors; consequently, the filter system is used to prevent overexposure or underexposure of colors.

There are approximately 130 different hues recognizable in the spectrum. Through experiments, it has been found that almost any color can be matched by mixing suitable amounts of red, green, and blue light. For this reason these three colors are known as the primary colors of light.

Red, green, and blue are the primary divisions of the light spectrum. Since all colors can be formed by combining these colors, the combination of any two of the primary colors will produce a secondary color. These combinations are shown in figure 3-44. The chart illustrates that we can produce three secondary colors, magenta, yellow, and cyan, with the proper combinations of the primary colors. Each color on the color star has a color directly opposite it. This is the complementary color for that color.

By interposing filters of various colors between the light coming from the subject and the image created by this light, we use subtractive color filtration. As this is explained, carefully study the two illustrations in figure 3-45.

First, let us consider the effect produced when the primary-colored filters are used upon a source of

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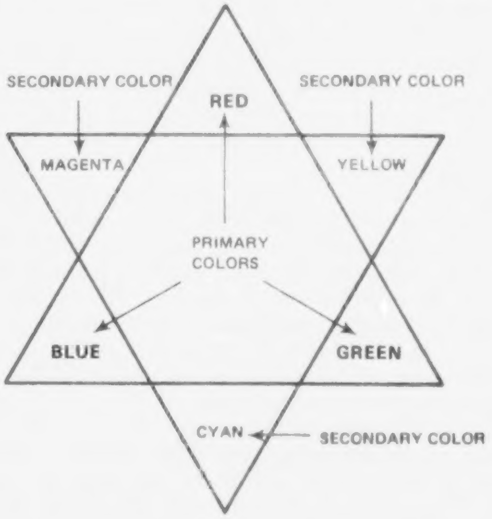

RED + GREEN = **YELLOW**
RED + BLUE = **MAGENTA**
BLUE + GREEN = **CYAN**

Figure 3-44. Color chart.

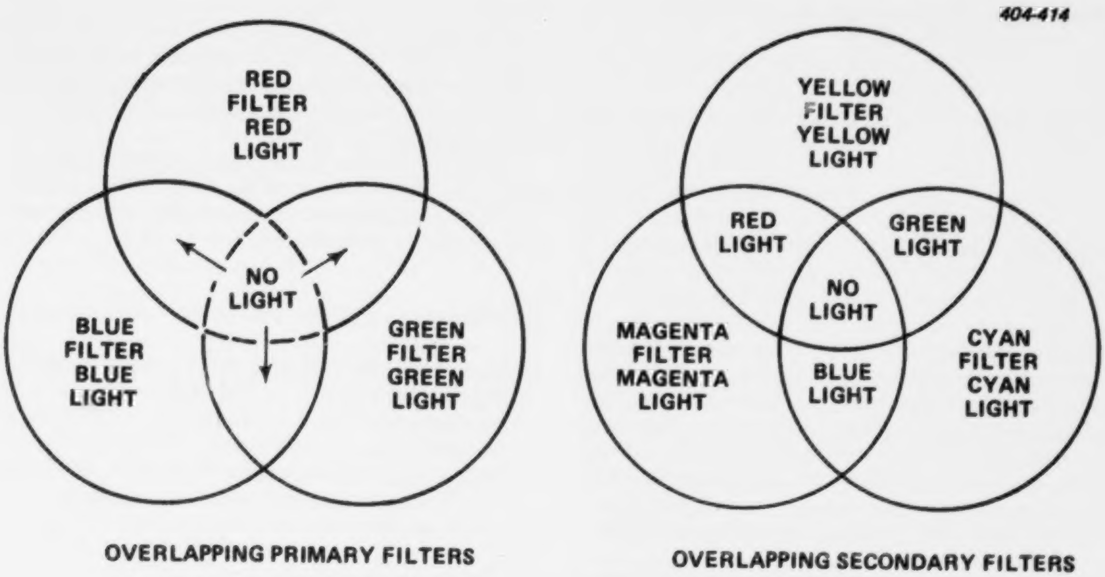

Figure 3-45. Subtraction color filtration.

white light. Notice that each primary-colored filter passes only its own color and absorbs the other two primary colors. When any two of the primary filters overlap, no light is allowed to pass; this also holds true if all three primary filters overlap. From this, we can establish that any primary color filter will pass its own color and block the other two primary colors.

Now consider the effects produced by secondary-colored filters (called subtractive primaries) on a source of white light. Each subtractive primary filter passes its own color or either of the two colors which combine to create it. For example, a yellow filter passes yellow light (it also passes red and green because they combine to form yellow). The yellow filter will not pass its complementary color, blue; and for this reason a yellow filter is often referred to as a minus-blue filter. Notice that total absorption of light by subtractive primary filters occurs only when all three filters are overlapped. From this we can see that a subtractive primary filter passes its own color or either of the two primary colors which combine to create that color and does not pass the primary color it complements.

It is often helpful to think of filters in terms of the colors they subtract from white light. Red is a minus blue and green, cyan is a minus red, and so on. In this way the result of the finished print from a black and white negative, can be calculated. Any color that is passed tends to print light because of greater negative density; any color that is not passed tends to print dark because of less negative density. The purity of the color of the filter and the purity of the color of light determine the exact transmission and absorption of the light from subject to the film.

*Effects of filters on the plane of focus*. Any glass filter will change the plane of focus of the image. When the filter is placed behind the lens, the glass displaces the image backwards one-third of the thickness of the glass filter. When a glass filter is used, it should be in front of the lens to lessen the image displacement. When using a filter, focus the camera on the ground glass with the filter in place.

*Limitations in using filters*. You must realize that filters cannot be used indiscriminately. Film sensitivity has a great deal to do with which filters can and which filters cannot be used. Orthochromatic film is relatively sensitive to blue and green, but has no sensitivity to red. If you use a red filter to make an exposure, the blue and green will be eliminated and no exposure will be obtained. The color of light may also place limitations on filters. If a subject is being illuminated with blue light, neither red, green, nor yellow filters should be used.

When filters are used, you must be completely familiar with the sensitivity of the film you are using and the nature of the illumination.

**Exercises (225):**

1. From the following list of filters, determine the color of light output if the input is white light.
   a. Red =__________.
   b. Cyan and magenta =__________.
   c. Green and blue =__________.
   d. Green and cyan =__________.

2. What effect do filters have on the image?

3. What determines which filter can or cannot be used?

**226. Identify the filter type from a list of filter forms.**

**Filter Construction.** Filters are designed and made to affect light in different ways. Hundreds of filters are available from different manufacturers, all designed for making definite changes or modifications in the light used for photography.

Aside from variations in color and density, colored filters are available in several different forms. Since there are hundreds of filters, to aid in identification the different forms of filters have been assigned to three general types according to their construction.

*Type 1*. Type 1 filters are plain gelatin filters made by adding suitable dyes to high-grade gelatin in solution. The dyed gelatin solution is spread on glass in a thin, uniform layer. After the thin gelatin layer has dried, it is stripped off the glass and cut into sheets. The gelatin sheets can then be cut to any desired size. Gelatin filters produce excellent results with a minimum of optical distortion in the filtered image. However, gelatin filters require extreme care in handling to prevent blemishes, fingermarks, and discoloration.

*Type 2*. Type 2 filters are prepared by cementing dyed gelatin sheets between pieces of carefully selected optical glass. Dyed gelatin filters are by far the most important because of the large number of dyes available. As mentioned earlier, plain gelatin filters are easily damaged, but this disadvantage is overcome by cementing the gelatin filters between pieces of hand-ground optical glass. These filters must be protected from heat, moisture, and excessive strain, which could cause the cement to give way, thus producing discolored blemishes which affect their performance.

The cemented filters are made in two grades—A and B. The grade denotes the optical quality. Grade A glass is optically flat and its surfaces are parallel. It is made to resist mechanical strains, which produce optical defects. For exacting work, this accuracy is essential.

Grade B filters are made of quality glass, but not designed for exacting work. They introduce some optical distortion in the filtered image, but give satisfactory results for many types of photography.

*Type 3*. Type 3 filters are the most permanent and are also of high quality, but cannot be obtained in as many colors as may be desired. Colored glass filters are produced by adding dyes to molten optical glass. The number of coloring substances that can be added to glass is limited, and it is difficult to produce a uniformly colored product. Furthermore, their absorption characteristics are not very adaptable to many panchromatic films.

As stated earlier, glass filters will affect the distance between the lens and the plane of focus. However, you can compensate by focusing on the ground glass with the filter in place.

Exercises (226):

1. Identify the type of filter from the following list of filter forms.
   a. Grade A.
   b. Grade B.
   c. Dyed gelatin sheets.
   d. Dyed gelatin cemented between glass.
   e. Colored glass.

**227. From given situations, determine the correct classification of filters to be used.**

**Classification of Types of Filters.** Filters are classified into types according to their transmission characteristics:

(1) Those which transmit all the visible spectrum, the transmission varying with wavelength.
(2) Those in which absorption for a portion of the spectrum is, for photographic purposes, complete.

The filters of the first type are referred to as correction, compensation, equalization, and sometimes orthochromatic filters, because they are used to obtain a more correct exposure.

Filters of the second type are usually termed contrast, selective, or separation filters, because they provide virtually complete absorption for certain colors in the subject being photographed.

*Correction filters*. Correction filters are used to achieve orthochromatic rendition (to reproduce color brightness in the proper relative shades of gray). A panchromatic emulsion is more sensitive to blue and red than it is to green and yellow. Therefore, it is sometimes necessary to use a filter to absorb portions of the blue and red. With a filter, this film can reproduce the brightness values as they appear to the eye. No one filter, of course, can have the same effect on all films under different types of light. For example, there are two types of panchromatic film: one has a relatively high green sensitivity and the other has a relatively high red sensitivity. Figure 3-46 lists the most commonly used corrective filters for both types of panchro-

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| TYPE | DAYLIGHT | TUNGSTEN |
|---|---|---|
| COLOR BALANCED PANCHROMATIC | MEDIUM YELLOW | LIGHT GREEN |
| HIGH RED SENSITIVITY PANCHROMATIC | LIGHT GREEN | MEDIUM GREEN |

Figure 3-46. Correction filters.

matic emulsions with both daylight and artificial light.

*Contrast filters.* Contrast filters are used to exaggerate or eliminate a color or colors. Contrast filters are usually very deep in color and are used to differentiate between two colors of equal brightness that would otherwise appear as identical shades of gray. As an example, suppose that you have a blueprint to copy. A blueprint consists of white lines on a blue background. Without a filter, the blue background exposes the film as much, or nearly as much, as the white lines, and there is little or no contrast. However, if you use a panchromatic emulsion with red or a deep-yellow filter to absorb the blue, only the white lines expose the emulsion. This produces a negative with density in the area of the white lines and no density in the area of the background. A print from this negative has white lines on a black background.

In an outdoor scene, you need to photograph a green barn with a red truck parked in front of it. The difference between the barn and truck can easily be seen by the eye because of the difference in color. But, in a photograph made without a filter, the colors would appear as equal shades of gray. You can correct this by using a red filter on panchromatic film so the print will show the barn to be dark and the truck light. Or using a green filter, the barn will appear light and the truck dark.

In many cases it is difficult to draw a line and state that one filter is a correction filter and another is a contrast filter. The classification depends upon the purpose for which it is being used and the sensitized material being used.

*Neutral density filters.* Neutral density filters are used for reducing the intensity of the light without affecting the color of the light. Suppose you are photographing a bright scene in sunlight with an extremely fast film in your camera. In this situation, even though you use the fastest shutter speed available on your camera, you may not be able to stop down the diaphragm small enough to obtain a correct exposure. A neutral density filter can solve this problem by reducing the amount of light before it passes through your camera lens.

A neutral density filter differs from other filters in that it partly absorbs all visible light colors equally. Since such a neutral density filter does not change the color of the light that it transmits, you can use such a filter with color and black-and-white film, and for contact and projection printing. Neutral density filters are available in a wide range of densities, allowing you to select the filter density that gives you the light absorption value you desire.

*Safelight filters.* The purpose of a safelight filter is to provide the darkroom technician with illumination without exposing the photographic material. Safelight filters transmit the maximum visible light to which the sensitized material is least sensitive. The various types of sensitized materials and the proper safelight to use are as follows:

- Graded contact and projection papers may be developed under a Wratten Series OA (greenish-yellow) safelight.

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| "WRATTEN" NUMBER | COLOR | USED WHEN PROCESSING |
|---|---|---|
| OA | GREEN-YELLOW | BROMIDE AND CHLORIDE PAPERS |
| 1 | RED | ORTHOCHROMATIC FILMS |
| 2 | DARK RED | HIGH-SPEED ORTHOCHROMATIC FILM |
| 3 | DARK GREEN | PANCHROMATIC FILM |
| 6B | AMBER | X-RAY OR DENTAL FILMS. NOT RECOMMENDED FOR ANY OTHER PHOTOGRAPHIC FILMS |
| 7 | LIGHT GREEN | INFRARED FILMS |
| 8 | DARK YELLOW | "KODAK COLOR PRINT FILM, TYPE 5381" |
| OC | LIGHT AMBER | VARIABLE CONTRAST PAPERS |
| "DUPONT S55X" | ORANGE-BROWN | VARIABLE CONTRAST PAPERS |

Figure 3-47. Safelight filters.

- Variable contrast papers may be processed under a Wratten Series OC or a DuPont S–55X safelight.
- Blue-sensitive films may be processed using a Wratten Series 1 filter.
- Orthochromatic films may be processed using a Wratten Series 2 filter.
- Panchromatic films may be inspected (after 50 percent of the developing time has elapsed) under a Wratten Series 3 (dark green) fitted safelight.

Any safelight is best when it gives indirect or reflected light. If a safelight gives only direct light, it should never be pointed straight at the sensitized material, but should be placed so that the light beam is pointed away from or at an angle to your work. See figure 3-47 for a selection of safelight filters for sensitized materials.

*Handling and care of filters.* All filters must be handled very carefully and cleaned only when absolutely necessary. Filters are precision accessories and should be treated as carefully as fine lenses.

To clean glass filters, first remove dust and lint from the surface with a soft camel's-hair brush. Condensation created by breathing on the filter provides adequate moisture for cleaning any material that will not brush away. Use only clean lens tissue to clean and polish the filter surfaces.

Clean gelatin filters only with a soft brush. Any attempt to clean them with lens tissue or moisture from your breath will damage the surface of the filter.

**Exercises (227):**

1. If the camera shutter speed and f/stop combination cannot decrease the light intensity to a satisfactory level, what filter should you use?

2. If you wish to separate two colors of identical brightness in a scene, what type of filter would you choose?

3. What type of filter would you use in a safelight if you were processing panchromatic film?

**228. Given hypothetical work situations where photographic filters are required, calculate the increase in exposure needed to produce the same density.**

**Filter Factors.** When you use a filter to absorb some of the radiation to which the emulsion is sensitive, the exposure time, the lens aperture, or the illumination on the subject must be increased if you are to obtain the same exposure on the negative as when no filter is used. If any two of the above factors remain constant, the third factor must be changed to retain the same exposure. The amount by which the exposure is increased is represented by a number called a *filter factor.* The factor is established by the film manufacturer for each type of film, filter, and light source.

Therefore, if the subject illumination and the lens aperture are constant, the filter factor is the ratio of the times of exposure with and without a filter to achieve the same exposure.

The filter factor depends upon (1) color and density of the film, (2) color of illumination, (3) sensitivity of the film, (4) reflective properties of the subject, and (5) processing conditions.

Filter factors are numerical designations to show the required multiplication factors. A factor of 1 indicates that no increase in exposure is needed. There are three commonly used methods of calculating exposure when using a filter. These methods are:

*a.* The shutter speed may be multiplied by the filter factor. For instance, a shutter speed of $^1/_{60}$ when multiplied by a factor of 2 ($^1/_{60} \times 2 = {}^2/_{60} = {}^1/_{30}$) would give $^1/_{30}$ as the new shutter speed.

*b.* Every time the factor is doubled, the diaphragm may be opened up one stop. Thus a factor

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FILTER FACTORS

| COLOR | FACTOR | |
|---|---|---|
| | DAYLIGHT | TUNGSTEN |
| LIGHT YELLOW | 1.5 | 1.5 |
| YELLOW | 2 | 1.5 |
| LIGHT GREEN | 3 | 2 |
| GREEN | 5 | 3 |
| DEEP YELLOW | 3 | 2 |
| RED | 8 | 4 |
| DEEP GREEN | 8 | 8 |
| BLUE | 5 | 10 |
| DEEP RED | 16 | 8 |
| DEEP BLUE | 12 | 25 |

Figure 3-48. Filter factors

of 2 calls for one stop, a factor of 4 calls for two stops, and a factor of 8 calls for three stops, etc.

*c*. The filter factor can be divided into the film speed (ASA). For example, if you were using a film with an ASA speed rating of 50 and a filter factor of 2, you would divide 50 by 2 (50 ÷ 2 = 25), and 25 would be the applicable film speed.

Filter factors for some of the most commonly used filters are given in figure 3-48. Film data sheets provided with the sensitized material normally contain both the filter factor and filter data that are recommended for that specific film.

When two filters are used in combination, their respective factors are multiplied, not added, to obtain the combination factor for both. This does not work, of course, with filters that cancel each other out, particularly if they are deep-colored filters that absorb a wide band of the spectrum. For all practical purposes, multiplying factors will work with any combination of a neutral density and any color filter, or with any two color filters whose multiplied factors do not exceed 40.

Exercises (228):

Referring to figure 3-48, determine the new shutter speed necessary to keep the same exposure without a change in f/stop.

| | *Original Exposure* | | *Color Filter* | *Type of Illumination* |
|---|---|---|---|---|
| | *f/stop* | *Shutter Speed* | | |
| 1. | 22 | 1/100 | yellow | daylight |
| 2. | 11 | 1/50 | green | daylight |
| 3. | 16 | 1/200 | red | tungsten |
| 4. | 22 | 1/100 | blue | daylight |
| 5. | 8 | 1/30 | deep red | tungsten |
| 6. | 11 | 1/100 | deep blue | daylight |
| 7. | 22 | 1/200 | light green | tungsten |

## 3-5. Sensitized Materials

Now that you have an understanding of the light properties used in making a photograph, let us discuss the medium on which the light is recorded in the camera and the medium on which the print is made.

**229. State the qualities and types of film bases, and explain the emulsion and coatings used on photographic films.**

One of the most curious of all photographic phenomena is the phenomenon of the latent image—the invisible image retained in the emulsion from the moment of exposure to the beginning of development. Looking at a sheet of undeveloped film in daylight gives no clue to the mysterious qualities it possesses—all you will see is a smooth, cream-yellow coating on a flexible support with perhaps a colored dye on the back of the film. All the amazing potentialities of film are totally invisible.

**Base.** The material selected as a base or support for a film emulsion must possess two qualities. First, it must be photographically inert—unable to cause any harmful action in the emulsion, either to the latent image or to the silver grains of the developed image. Second, it must remain unaffected by the solutions used in processing. Many materials meet these qualifications, but some of the most commonly used are cellulose acetate, glass plate, and polyethylene terephthalate.

*Cellulose acetate*. Cellulose acetate is commonly used as a support for negative emulsion because it is transparent, strong, lightweight, and flexible. In addition, cellulose acetate bases are usually considered safety films, because they have the advantage of low flammability. They will burn or smolder, but only as long as a flame is in direct contact with them. When burning, the fumes are disagreeable but not toxic.

The cellulose acetate film bases do not have a surface to which the emulsion coating will readily stick. Therefore, it is given a special coating to prevent the emulsion from swelling loose or frilling when wet, and peeling or stripping when dry. The base is given a thin coating of a solution composed of gelatin and cellulose which is dried before the emulsion is applied.

*Glass*. Glass plates have been used as a light-sensitive emulsion support for a negative since the earliest days of photography. For many years it was the only photographically inert support that fulfilled the requirements of transparency and stability. That is, glass produced no harmful effects on the light-sensitive emulsion, on the exposed silver halides, or on the developed image.

Glass is still used for special purposes for which rigidity and freedom from expansion and contraction are important, such as in various forms of photogrammetry and for lantern slides. However, glass has the disadvantage of bulk, weight, and inflexibility, and is easily broken. Consequently, glass has been largely replaced by the more convenient cellulose-based films.

*Polyethylene terephthalate*. Polyethylene terephthalate is a type of polyester that is relatively new to the film base field. Films made with terephthalate polyester have great dimensional stability and tear resistance, making them excellent for use in the graphic arts field, industrial uses, and aerial photography. Because of the toughness of this base, it has made possible the introduction of thin base roll film. This has increased the film load capacity of cameras.

**Emulsion.** The emulsion that is applied to the base material is composed of a mixture of silver salts called halides and gelatin. The halides, silver bromide and silver iodide, usually are used together in film emulsion. As previously mentioned, these halides are affected by light to form the latent or invisible image. The image becomes visible only upon treatment in a chemical solution called a developer.

The silver halides are exposed in proportion to the quantity of light striking them. A large quantity of light reflected from a light object will expose a thicker layer of halides, and a small quantity of light reflected from a dark object will affect a thin layer or none at all. These affected silver halides will then be changed into black metallic silver by the developer to form a visible image.

*Protective coating.* One type of dark streaks which occasionally appear on developed film are caused by the light-sensitive surface being subjected to friction, scratches, or abrasion prior to development. The affected portions of the emulsion are rendered developable where stress occurs from mechanical action. This effect can be prevented to a large degree by the application of a thin overcoating of clear gelatin to protect the emulsion. This overcoating or antiabrasion layer is used on amateur rollfilms and film packs because the emulsion surface of these films is abused under normal conditions. This protective coating can also be applied to sheet film and aerial films.

*Noncurl coating.* A film emulsion swells when wet and shrinks when drying. The contractions produce a strain on the flexible film base and cause it to curl. A coating of hardened gelatin, approximately the same thickness as the emulsion, is applied to the back of most films to counteract the curling. The coating contracts equally but in the opposite direction to the emulsion. This reduces the curling by balancing the shrinking strains.

*Antihalation backing.* The antihalation dye, sometimes incorporated into the anticurl backing, is a thin layer of dye that prevents reflex halation. This type of halation forms the halo or bright image circle that can sometimes be seen around the photographic image of a bright object.

Halation is produced when light, which has passed through the emulsion, is reflected back into the emulsion by the surfaces of the base so that it forms a secondary, scattered, circular image of a bright image point.

The dye used to eliminate halation is the color to which the emulsion is least sensitive, so the reflected light has little or no harmful effects. The dye used is soluble in water and is dissolved during normal processing.

Figure 3-49 shows the normal composition of film. All films contain the base and emulsion, while the other coatings are applied to film for specific use. In addition, some films contain special emulsions to change their characteristics for light conditions, light color, and uses. Regardless of application, the photographic film is the medium for producing the latent image from reflected light to produce a photograph.

**Exercises (229):**

1. State the two qualities a photographic film base must possess.
2. Which of the three film bases is usually considered as safety film?
3. What are the disadvantages of using glass as a photographic film base?
4. Which type base is used for making thin base aerial roll film?
5. What is the film emulsion made of?
6. What is the purpose of the protective coating on film?
7. What is the noncurl coating made from to prevent film from curling?
8. What is the purpose of the antihalation backing?

### 230. State the characteristics and composition of photographic paper bases and emulsions.

Once the latent image is developed, the next process is to change the negative image to a positive picture. The latent image on the film is reversed from the normal photograph with which you are familiar. This was explained earlier in this section during the discussion of light exposing the silver halides. White objects will expose many layers of the silver halides, causing metallic black silver to form. Thus, white objects become black on the film. To reverse this, the image is printed on a positive medium. We will now

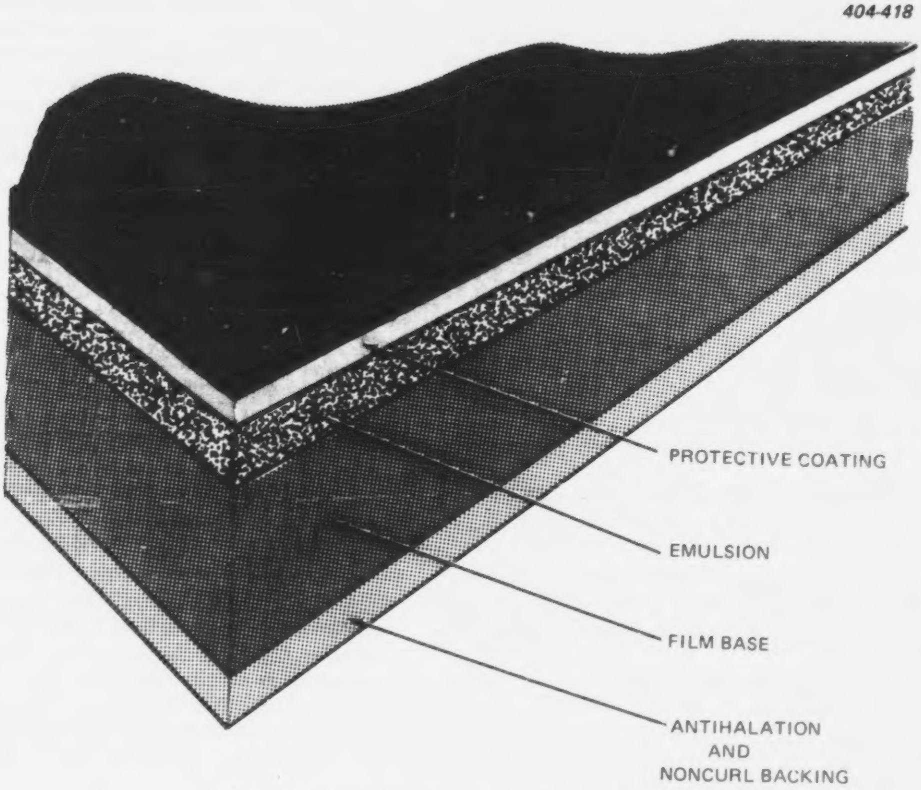


Figure 3-49. Cross section of photographic film.

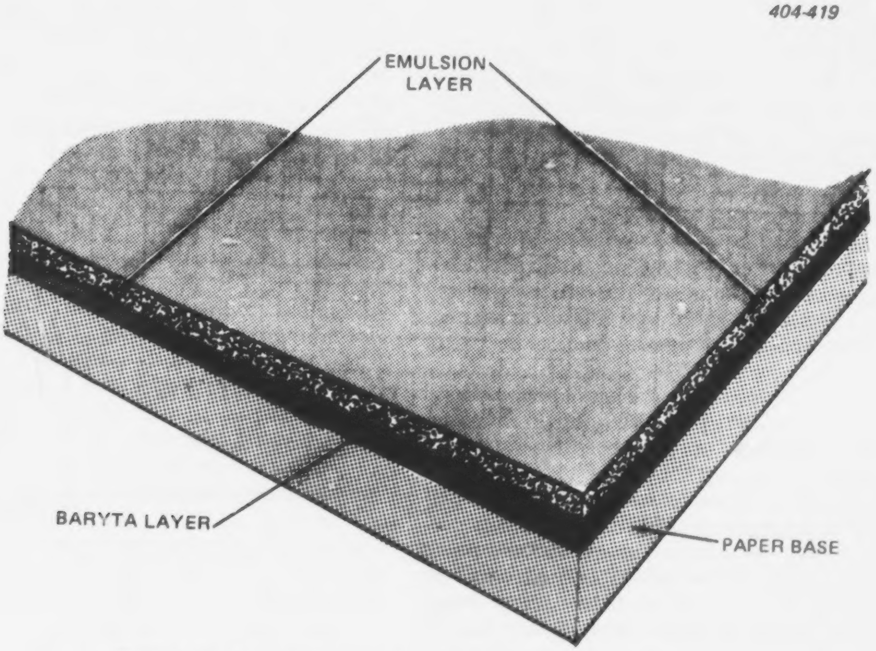


Figure 3-50. Cross section of a sheet of photographic printing paper.

discuss the composition of photographic positive mediums. See figure 3-50.

**Base.** The paper used as the base for emulsions is the highest grade of paper available. Today, the most stable papers are made from high-grade sulfite woodpulp. This superior paper is able to absorb punishment that would ruin ordinary paper. It withstands alkaline and acid solutions, handling while wet, and thorough washings. Its chemical purity prevents chemical reactions with the solutions it encounters during processing.

The paper bases are manufactured in several different thicknesses to be used for specific requirements. The three general thicknesses of paper bases are light weight, single weight, and double weight.

*Light weight.* This paper is furnished in a thin or light-weight stock and is intended for purposes which frequently involve folding. To produce the light weight, the baryta coating (to be explained later) is not applied to the base. The thickness of the paper base makes it ideal for use in making photocopying papers.

*Single weight.* Single-weight paper is relatively thin. It is about half as thick as the double-weight stock, and is used for all ordinary photographic purposes.

*Double weight.* Double-weight paper is thicker than the average heavy post card. It is the heaviest stock normally used for photographic paper. However, there are emulsions supplied on cardboard-weight base for making post card prints.

Double-weight paper bases are generally used for large prints because they stand up better under rough treatment. The double-weight paper is also generally used for portraits and exhibition photographs.

The three paper stocks all have one thing in common. In the photo processing procedure they absorb processing solutions. The absorption causes expansion and contraction in the paper and requires an extended washing time to remove these chemical solutions. This washing time causes an extended drying time.

To overcome these disadvantages, the paper bases can be procured with an acetate coating applied to the back of the base. This acetate coating prevents absorption of chemical solutions and water, thus allowing quick production time of prints when necessary.

*Baryta layer.* Once the paper base is prepared and dried, it is coated with a very thin layer of baryta, which fills in the pores of the paper fibers and provides a smooth surface for the emulsion coating. The baryta coating is composed of barium sulfate and gelatin, which is insoluble in water. This special coating process also greatly increases the reflecting power of the paper. The added brilliance of the baryta coating is an important factor in the detail and clarity of the finished photograph. This coating is not applied on papers that may be folded or creased for handling. The baryta coating is brittle and would cause the emulsion to crack if it were folded or creased.

**Emulsion.** The light-sensitive coating on the paper bases may be an emulsion made of silver chloride, silver chlorobromide, or silver bromide, with their sensitivity to light increasing in that order. The chemical composition of these silver compounds, the method of their formation, and the addition of special agents determine the properties of light sensitivity and contrast. The various combinations of silver compounds differ greatly in their response to the action of light, and the papers are classified accordingly.

The latent image from the negative is printed onto the paper emulsion by use of an artificial light source. The light passing through the film will react to the paper emulsion the same way as it did on the film. The areas that are dark on the film will expose fewer silver compound layers on the paper, while the light areas on the negative will expose a large quantity of silver compound layers on the paper. This will produce the reversed image from the film to the paper.

As with films, there are many types of papers that are used in photography. These papers fall into two categories—projection and contact printing. The types and grades are numerous, but each paper is composed basically the same way. Only the emulsion layer is different to meet the specific requirements for a particular photographic mission.

Exercises (230):

1. What is the requirement for a paper used to make a suitable base for photographic paper?

2. Which thickness of base is used to make photocopy paper?

3. Which thickness of base is used to make portraits?

4. Which thickness of base is used for ordinary photographic purposes?

5. What is the composition of baryta coating?

6. Under what conditions can you not use a paper which has a baryta coating?

7. What are the three light-sensitive coatings used on photographic papers?

8. What do the chemical composition, method of formation, and special agents determine in a photographic emulsion?

## 3-6. Chemistry of Photography

When an exposure is made, a chemical reaction takes place in the light-sensitive emulsions of film and paper. During the chemical change, the silver halides in the emulsion layer produce a latent, or invisible, image in the emulsion.

The latent image in the exposed emulsion is made visible by the process that is termed development. Chemical development is the reduction of the exposed silver halides in the emulsion to blacken (free) metallic silver. This process is performed in solutions that contain various mixtures of chemicals.

### 231. Explain the theory of development and state the purpose of the four essential ingredients in a developer.

**Theory of Development.** When a photographic emulsion is properly exposed to light with a camera, printer, or enlarger, an invisible change in the minute crystals of silver halide is produced. This change results in the formation of the latent image. To obtain the visible image, the exposed emulsion has to be treated in a solution known as a developer. This solution converts the light-affected halides to black metallic silver. These black metallic silver particles form the visible image.

There are many theories as to the exact nature of the change or reaction that takes place when a light-sensitive material is exposed to light. However, it is sufficient to know that the light affects the halides in such a manner as to permit their reduction to a metallic silver. Reduction is accomplished with a chemical known as a reducing agent. In Air Force photographic terminology, this reducing agent is commonly referred to as a developing agent.

The theory involved in developing latent images is essentially the same for both negatives and prints, whether they are made on paper, film, or glass. The negative image in most cases precedes the positive image in making a photograph. Therefore, we will be going primarily through the process of the negative image.

Processing chemicals behave differently under varying conditions, but always according to a fixed pattern. Any chemical reaction may be obtained at any time by setting up exactly the same set of conditions. These conditions consist of differences in degree of chemical concentration, variations in temperature, and variations in the time the action is continued.

**Basic Developer.** There are many different formulas used as developing solutions, but most all modern developers contain the following four essential ingredients—developing agent, preservative, accelerator, and restrainer.

*Developing agent.* The developing agent (reducing agent) is the most important chemical in a developing solution. Nevertheless, the other ingredients are necessary to make the solution function properly. Although several chemicals are capable of developing silver halides to metallic silver, relatively few of them can be used. Many chemicals tend to develop the unexposed as well as the exposed silver halides; that is, some are not selective in their action. The few developing agents that are used vary greatly in their properties.

One of the properties of a developing agent is its reducing potential. This refers to its relative ability to develop or reduce the silver halides. A developing agent of high potential attacks silver halides vigorously, whereas one of low potential is slower in its action. The characteristic activity of a developing agent is another factor to consider. Some agents are more active in strongly exposed areas, some weak in the weakly exposed areas, and others have an equal overall activity. The temperature of the solution affects the activity of some agents much more than others. The tone of the developed image is greatly affected by the type of developing agent. Some agents produce blue-black or cold tones, while others yield brownish or warm tones. Hydroquinone, Metol, Amidol, glycin, *para*phenylenediamine, and pyro are some of the more widely known developing agents.

*Preservative.* All organic developing agents in an alkaline state have a strong affinity for oxygen. It is necessary, therefore, to add a preservative to developing solutions to prevent excessive oxidation. The preservative prolongs the useful life of the developing solution and prevents the formation of colored oxidation products, which cause stains.

The preservative is a chemical that has a very great affinity for free oxygen and combines with it when mixed in a solution. A large amount of free oxygen is in the air and in the water used for solutions. If the free oxygen is left in the water, it oxidizes most of the developing agent and produces stains before the metallic silver image is satisfactorily developed. By the addition of a sufficient quantity of preservative, practically all of the free oxygen is removed from the solution, the developing agent works as intended, and no stains are produced.

The quantity of preservative used varies greatly as shown by the following factors, which determine the amount required:

(1) The tendency of a developing agent to oxidize.

(2) The concentration of the developer.

(3) The temperature at which the developer is stored or used. The rate of oxidation increases as the temperature increases.

(4) The keeping properties required and the way in which the solution is used. A solution that is to be used only once and then discarded requires very little preservative. Furthermore, oxidation is more rapid when developing in a tray than when used in a tank.

(5) The alkalinity of the solution.

*Accelerator.* All developing agents are either neutral or slightly acid and, as such, they usually have little developing ability. In order to utilize the developing capabilities of these agents, it is necessary that they be in an alkaline state. To make the developing solution alkaline, an accelerator is added.

The accelerator has double action. First, it hastens the swelling of the gelatin in the emulsion, permitting the solution to penetrate the entire emulsion more quickly. The second action is completely chemical. As the silver halogen salts in the latent image are reduced by the developing agent, the halogen elements liberated from the silver are absorbed by the accelerator and combined into neutral salts so they do not have any harmful effects in the solution. These halogen salts cause some difficulty in one form or another if they are not absorbed by the accelerator. In some developers, the accelerator is utilized in this manner as a part of the developing agent, but the final result is the same as if appearing in separate chemicals. It swells the gelatin to hasten saturation, and then absorbs the halogen salts as they are released from the silver compound by the action of the developing agent.

*Restrainer.* Without a restrainer, most developing solutions act too rapidly and develop unexposed silver halides near the surface of the emulsion. This causes chemical fog, developing streaks, and an image lacking in contrast. When a restrainer is added, developmetn time is prolonged, and fog is minimized. Contrast is increased because the developing agent's activity is cut down in unexposed areas. Excessive amounts of restrainer can greatly retard development.

The restrainer acts as a break on the combined action of the developing agent and the accelerator. No accelerator known supplies exactly the required increase in developing speed. All of them produce more activity than desired. Therefore, to control the action, a restrainer is added to hold the action within usable limits.

The ideal developing solution is one that develops all the exposed silver halides in the emulsion and has no effect on any that are not exposed. When all the exposed parts of an emulsion have been developed, the action should stop, even though the film is left in the solution. All solutions require attention during processing in order to stop their action when the desired results have been produced.

**Exercises (231):**

1. Explain the action of the developer on the exposed silver halides.

2. What are the conditions required to obtain exactly the same results from a chemical reaction?

3. What is the purpose of the reducing agent?

4. What is the purpose of the preservative?

5. What factors determine the quantity of preservative used in a developer?

6. State the purpose of an accelerator, and explain its action in a developer.

7. State the purpose of a restrainer and its effects on development.

**232. State the purpose of the stop bath and specify the uses of the different types.**

**Stop Bath.** When a negative or print is removed from the developing solution, there is a small amount of developer both in the emulsion and on the surface of the film which must be removed or neutralized to stop its action and to prevent stains. To remove the developer from the negative, it should be immersed in a rinse bath. Rinse baths are of three general types—water, acid, and hardening. Each of these rinse baths has a specific purpose and should be used accordingly.

*Water bath.* A water rinse bath helps retard the action of the developing agents and removes the excess developer from the emulsion, thus preventing contamination of the fixing bath. It is suitable and sufficient for most negatives. A water rinse may also precede the acid rinse when processing prints.

*Acid bath*. An acid bath, sometimes referred to as a stop bath, instantly neutralizes the alkalinity of the developer, stopping further development, and prolongs the useful life of the fixer by preventing developer carryover.

Due to the soft emulsion and the nonabsorbent quality of the base of most negative materials, only a very weak acid rinse is required. Usually, however, only a water rinse is used between development and fixation of most negative materials. If a weak acid rinse is not used, all emulsions should be thoroughly rinsed in water before they are placed in the fixing bath.

*Hardening rinse*. A hardening rinse should be used if processing must be done where it is impossible to control the temperatures of solutions, particularly the wash water.

**Exercises (232):**

1. State the purpose of a stop bath on the processing procedures for sensitized materials.

2. When would you use each of the following?
   a. Water bath.
   b. Acid bath.
   c. Hardening rinse.

**233. State the purpose of the five basic ingredients used to make a fixing bath.**

**Fixing Bath**. When a light-sensitive material is removed from the developing solution, the emulsion contains a considerable amount of silver salts that have not been affected by the developing agents. These silver salts are still sensitive; and if they are allowed to remain in the emulsion, light ultimately darkens them and obscures the image. Obviously, if this action occurs, the negative is useless.

The fixing bath is employed to prevent this discoloration and to assure permanency of the developed image. It accomplishes this task by dissolving the halogen salts of silver from the developed free silver image. Therefore, to make an image permanent, it is necessary to "fix" the light-sensitive material by removing all fo the unaffected silver salt from the emulsion. The fixing bath contains five basic ingredients—the fixing agent, the preservative, the neutralizer, the hardening agent, and the antisludge agent.

*Fixing agent*. All fixing baths must contain a silver halide solvent. This solvent is known as the fixing agent. The silver salts for which this agent must be a solvent are silver chloride, silver bromide, and silver iodide. The primary purpose of the fixing agent is to convert these silver salts remaining in the emulsion after development to soluble compounds and to remove these soluble compounds by constantly diluting and replacing them in the emulsion.

*Preservative*. A preservative prevents oxidation of the developing agents that are carried over into the fixing bath by the film and also prevents decomposition of the fixer. Oxidized developer in a fixing bath produces stains.

Strong acids tend to cause a fixing agent to decompose (sulfurize). The preservative acts as a buffer to protect it. Therefore, it is most important to dissolve the preservative in the fixing solution before adding the neutralizer, or the acidifier as it is sometimes called. To prevent the decomposition of the fixer, a preservative is added.

*Neutralizer*. After development, the pores of the swollen emulsion retain a portion of the developer. If allowed to remain, the developer continues to be active. Even though the emulsion is thoroughly rinsed in a nonacid bath before it is placed in the fixing solution, a sufficient amount of developer remains to continue this activity. This causes uneven stains in the gelatin of the emulsion, which renders the negative unfit for use. To stop development and prevent staining, a neutralizer is added to the fixing bath.

The neutralizer stops the action of the developing solution remaining in the emulsion when the film is immersed in the fixing bath. The developer solution is alkaline, and its action stops when this alkali is neutralized by the acid. The one most frequently used is acetic acid.

*Hardener*. It was stated earlier that during development the emulsion swells and becomes soft. This softened emulsion can be scratched, frilled, or otherwise damaged as a result of handling during processing. To prevent this, a hardener is added to the fixing bath. This allows the emulsion to be fixed and hardened at the same time. The hardener stops the tendency of the emulsion to swell and leaves the emulsion expanded but firm for the washing process.

*Antisludge agent*. The chemicals used in the fixing hardening bath have the disadvantage of greatly increasing the retention of fixer by the negative. To reduce this effect, the acidity range of the bath is limited. The reduced acidity of the bath is further neutralized by the alkali of the developer carried into the fixing bath by films. When the active acidity is neutralized too far, a chemical sludge forms which renders the bath useless. Boric acid added to the fixing hardening bath absorbs a large quantity of the developer before the sludge can form, and the useful life of the bath is lengthened. Therefore, the antisludge minimizes sludging tendencies of fixing hardening baths and improves their hardening properties.

Once the fixing bath time is completed, the negative is removed from the bath and placed in a wash bath. The washing cycle should be long enough in

**Exercises (233):**

length to assure the removal of the chemicals from the negative. To speed up the time, the negatives should be washed in running water.

**Exercises (261):**

1. State the purpose of a fixing agent.

2. What is the purpose of the preservative in the fixing bath?

3. State the purpose of the neutralizer.

4. State the purpose of the hardener.

5. What is the purpose of the antisludge agent?

# Tools and Measuring Devices

IN THIS CHAPTER we will not attempt to cover all of the common handtools available for your use. There are so many types and variations of the basic tools—special designs and modified tools for specific jobs—that to discuss them all would make this section too long. If you should need information on specific tool use and care, you can find it in the TO–32 series.

## 4-1. Handtools

If special handtools are available in your maintenance shop, remember that the techniques of using and maintaining the tools that are covered in this section will apply to specially modified tools of similar design. Since you already know something about most of these tools, the discussion will be brief. However, read it carefully to refresh your memory on nomenclature and techniques that you may not have had occasion to apply.

### 234. State precautions to be taken when using handtools.

**Handtool Precautions.** A workbench and a consolidated tool kit (CTK) are normally provided to assure that you have a suitable work area, adequate storage space, and the provisions for proper use and care of all tools. Check your work area to see if you have the following:

*a.* Felt-lined drawers or a suitable substitute (for the safe storage of precision gauges, tweezers, jewelers' screwdrivers, and other delicate tools).

*b.* An electrical ground for any metal workbench (a safety factor to prevent electrical shocks).

*c.* A rubber mat for the floor in front of the bench (to minimize both the breakage hazard and the electrical shock hazard).

Let's cover some general precautions with respect to the care of tools. You should memorize the following:

*a.* Keep the workbench, the work area, and the CTK orderly. Know where each tool is so that you can get it immediately when you need it.

*b.* Always protect any cutting edges. Wrap tools having cutting edges with cloth if they are stored with other tools or keep tools with cutting edges in a suitable rack.

*c.* Keep all tool handles and working surfaces free from oil while working with tools. This reduces the probability that your hand or the tool will slip while you are working.

Where climate conditions are typically affected by tropical, polar, or maritime air masses, special precautions must be observed. You must always remember to apply the following measures:

*a.* Keep all tools not in use out of the sun in hot climates. When exposed to the sun for a long time in very hot areas tools may become hot enough to cause severe burns when you touch them.

*b.* Keep tools protected from prolonged exposure to any very hot, very dry environment. Extreme heat in an extremely dry climate evaporates the protective oil from the metal and leaves the tools dry and unprotected from rust and corrosion.

*c.* Keep tools dry. Dampness, salt-laden air, sleet, and snow are climatic conditions very conducive to rust and corrosion. By keeping tools off the ground, covering them with adequate protective material, and coating them with a thin film of oil when not in use, you minimize their deterioration.

*d.* Whenever possible, avoid exposing tools to rapid and extreme changes in temperature. Cold metals sweat when taken into a warm room. To prevent rusting, you must dry tools carefully when moisture condenses on them.

*e.* Never handle cold tools unless you wear gloves. The cold metal may freeze the natural moisture on the surface of the skin and cause the tool to stick to the skin, resulting in a painful injury.

**Safety Precautions.** It is extremely important for you to recognize the possibilities of injury when using hand tools, power tools, and measuring tools. The following safety precautions are included as a guide to prevent or minimize personal injury:

*a.* Make certain that all tool handles are securely attached before using them.

*b.* When handling edged tools, exercise extreme caution.

*c.* Do not use a tool for any purpose other than that for which it was intended.

*d.* Do not handle tools carelessly; piling tools in drawers, dropping tools on hard surfaces, etc., can damage them. Damaged tools can cause mishaps.

*e.* Keep your mind on your work.

*f.* Do not carry edged or pointed tools in your pocket.

*g.* Always wear goggles when chipping metal and when grinding edges on tools.

*h*. Hold driving tools so they will not slip off working surface.

*i*. Use the right tool for the job. The wrong tool can damage the equipment.

*j*. Do not use punches with improper heads.

*k*. Do not use a tool that is oily or greasy.

*l*. When using jacks, make certain to use blocking or other supports when lifting a vehicle.

*m*. Use torches and soldering irons with extreme care to prevent burns and explosions.

**Personal Safety Equipment.** To protect you from danger, protective equipment such as safety shoes, goggles, and gloves are issued. The use of this equipment is mandatory on certain jobs. Their use is a must, and there is no question about that. Be sure to use them on any job where they are required. They can protect you from a lot of harm.

***Safety shoes.*** Some safety shoes are designed to limit damage to your toes from falling objects. A steel plate is placed in the toe area of such shoes so that your toes are not crushed if an object impacts there.

Other safety shoes are designed for use where danger from sparking could cause an explosion. Such danger is minimized by elimination of all metallic nails and eyelets and the use of soles that do not cause static electricity.

***Goggles.*** Proper eye protection is of the utmost importance for all personnel. Eye protection is necessary because of hazards posed by infrared and ultraviolet radiation, or by flying objects such as sparks, globules of molten metal, or chipped concrete and wood, etc. These hazards are ever present during welding, cutting, soldering, chipping, grinding, and a variety of other operations. It is imperative for you to use eye protection devices such as helmets, handshields, and goggles during eye-hazard operations.

Appropriate use of goggles will limit eye hazards. Some goggles have plastic windows that resist shattering upon impact. Others are designed to limit harmful infrared and ultraviolet radiation from arcs or flames by appropriate filter lenses.

Remember, eye damage can be excruciatingly painful. PROTECT YOUR EYES.

***Gloves.*** Use gloves whenever you are required to handle rough, scaly, or splintery objects. Special flameproof gloves are designed for gas and electric welding to limit danger and damage from sparks and other hot flying objects. Personnel in the electrical fields are usually required to wear insulating rubber gloves.

Be sure to follow all regulations prescribed for the use of gloves. Gloves must not be worn around rotating machinery unless sharp or rough material is being handled. If such is the case, extreme care should be exercised to prevent the gloves from being caught in the machinery.

**Exercises (234):**

1. What should you make sure of when lifting a vehicle with jacks?

2. When you are grinding or chipping metal what should you wear?

3. What is the purpose of a steel toe safety shoe?

4. Safety gloves normally should not be worn around what type of equipment?

5. You finish a job away from the shop where the temperature is −10°F, and you return to the shop where the temperature is 70°F. What procedure should you use to maintain the tools you have on the flight line?

6. If you store a tool with a cutting edge, what procedure should you use for maintaining this tool?

### 235. State the purposes for which hammers and mallets are designed and the precautions to observe in their use.

**Hammers and Mallets.** Hammers and mallets are used to drive nails, spikes, drift pins, bolts, and wedges. They are also used to strike chisels and punches and to shape metals. Sledge hammers are used to drive spikes and large nails, to break rock and concrete, and to drift heavy timbers.

Hammers, like those shown in figure 4-1, are designed to do work that involves changing the shape of the article being struck, to do work where a minor amount of damage to the article being struck is not of any consequence, or to do work by striking something that is harder than the hammer.

The mallet has a soft head. The general shape of the mallet is shown in figure 4-2. It is designed so that you can apply force to some other material without damaging it. The weight of the mallet head does the work, but the soft material of the head does not damage the material being struck. Mallets have heads of brass, rawhide, rubber, lead, Babbit, or copper.

The nature of the job to be done determines the shape, size, and type of hammer or mallet to use. If the hammer or mallet chosen is the wrong shape, you do not have the right striking surface to do the work properly. If the tool is too large, the work may be damaged; if the tool is too small, the hammer or mallet may be damaged. If a mallet head is not soft enough, it damages the surface of the article being struck. Remember the following techniques:

*a*. Hold each of these tools near the end of the handle, with the hammer's face parallel to the work.

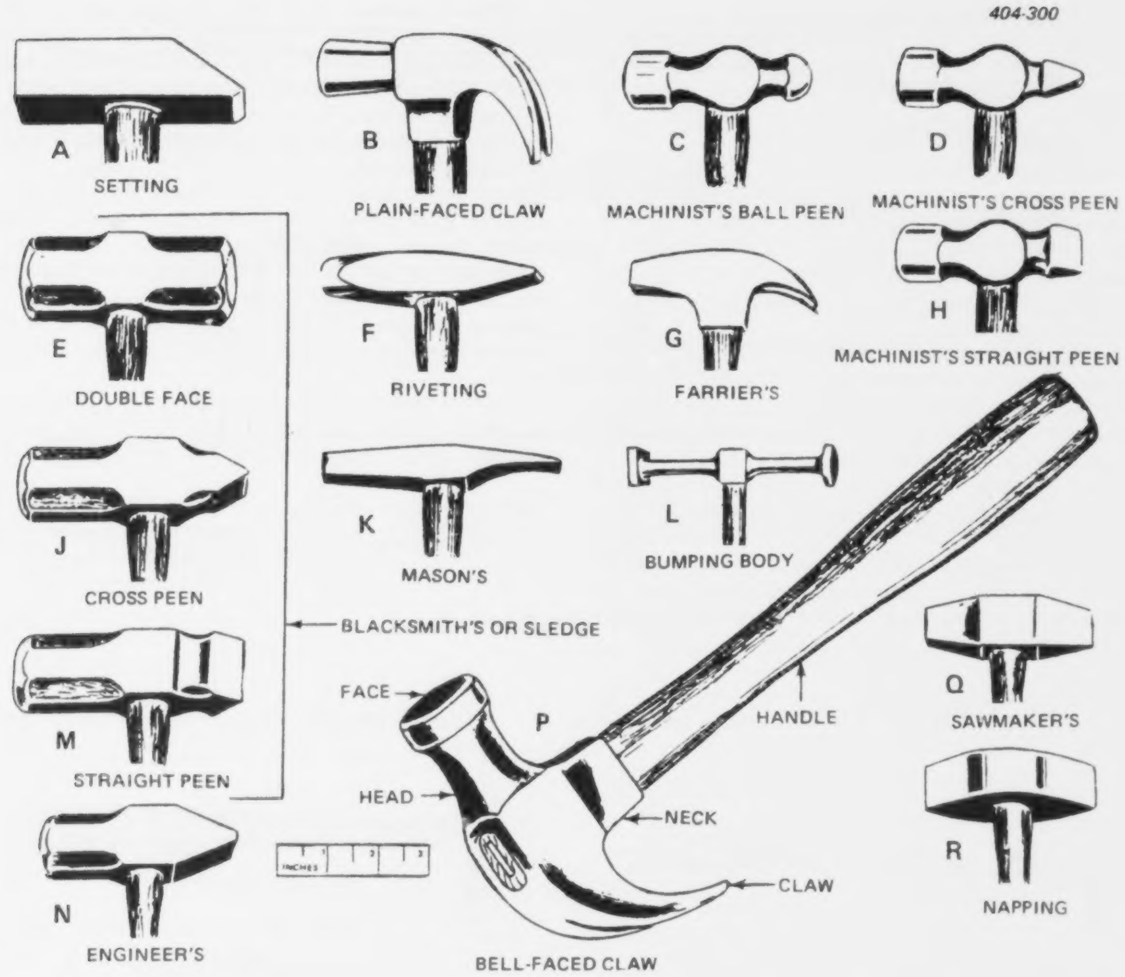


Figure 4-1. Types of hammers.

*b.* Grip the tool handle just tight enough to control the blow.

*c.* Move the head of the tool straight away from the work, using the elbow as a pivot point, and then bring it back into contact with the work with a quick, sharp motion.

The weight and amount of travel of the head determine the strength of the blow. Learn to estimate the force needed to do a task. Keep the blows even and your eyes on the spot being struck—not on the head of the tool.

Always observe the following safety precautions:

- Make sure the handle is clean.
- Keep the face of the hammer or mallet clean and properly dressed.
- Clean and dry your hands.
- Never use a hamer or a mallet with a loose head.

**Types of Hammers.** There are many types of hammers. Refer to figures 4-1 and 4-2.

As a photographic maintenance person you will probably not use all of the hammers shown in figures 4-1 and 4-2. The following is a brief description of some you might use.

***Carpenter's hammers.*** A carpenter's hammer is a steel-headed, wood-handled, nail-driving tool. There are two types of carpenter's hammers. Both types have claws at the back of the hammer head for pulling nails. However, the difference between them is their faces. One type has a flat face and is known as a plain-faced claw hammer (fig. 4-1B). The other type has a rounded or convex face and is known as a bell-faced claw hammer, shown in figure 4-1,P. Carpenter's hammers are made in various weights.

***Machinist's peen hammers.*** Machinist's peen hammers are generally used by machine shop personnel and auto mechanics. However, in your maintenance shop this hammer will be useful to you. Machinist's peen hammers are made in several different types.

*Ball-peen hammer.* The most common is the ball-peen hammer (fig. 4-1,C). It has a round, ball-shaped head and is used for general purpose work. Ball-peen hammers are classed according to the weight of the head without the handle. They usually weigh 2, 4, 8, or 12 ounces, or 1, 1¼, 1½, 2, or 3 pounds.

*Riveting hammer.* The riveting hammer (fig. 4-1,F) is used to peen the ends of rivets and to upset rivets. The round face is used for peening, and the narrow, tapered, chisel-like face is used to upset rivets.

*Setting hammer.* The setting hammer (fig. 4-1,A) is used for bending and beveling metal edges and for setting double seams in sheet metal.

***Blacksmith's or sledge hammers.*** Blacksmith's or sledge hammers are similar to machinist's peen hammers, except they are made for heavy duty. Short-handled sledge hammers are used to drive bolts, drift pins, and large nails. Long-handled sledge hammers are used to break rock and concrete. The sledge hammers in figure 4-1,E, J, and M are made in weights of 6 to 20 pounds and have handles 30 to 36 inches long.

***Bumping body hammers.*** A bumping body hammer (fig. 4-1,L) is used for straightening and bumping metal. The hammer shown has one round and one square face, and the head is 4 inches long.

***Welder's hammer.*** A welder's hammer (fig. 4-2,A) is used for chipping welds. The opposite end of the hammer is sometimes equipped with a wire brush for cleaning metals before welding and for brushing slag away after chipping.

**Types of Mallets.** There are many types of mallets, but the ones you will be concerned with are carpenter's mallets and rawhide mallets.

***Carpenter's mallet.*** A carpenter's mallet (fig. 4-2,H) is a wooden, short-handled tool used to drive wooden-handled chisels, wooden dowels, or small stakes. The head is cylindrical and has two flat driving faces. It is sometimes reinforced with iron bands at each end. This mallet is also used for smoothing out dents in sheet metal and for turning thin metal edges and seams without cutting the metal surface.

***Rawhide mallet.*** The rawhide mallet (fig. 4-2,K) is used to form or shape sheet metal where hard-faced or steel hammers might damage the metal.

**Exercises (235):**

1. What is the purpose of the setting hammer?

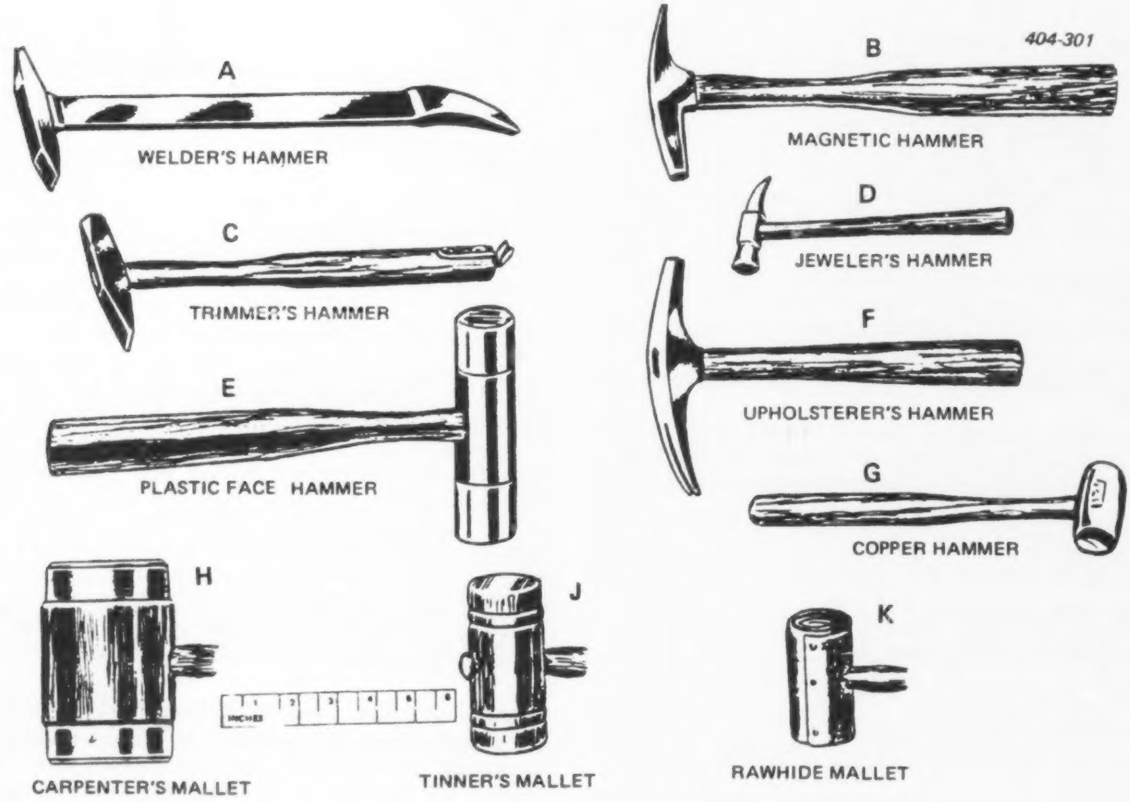


Figure 4-2. Mallets and hammers.

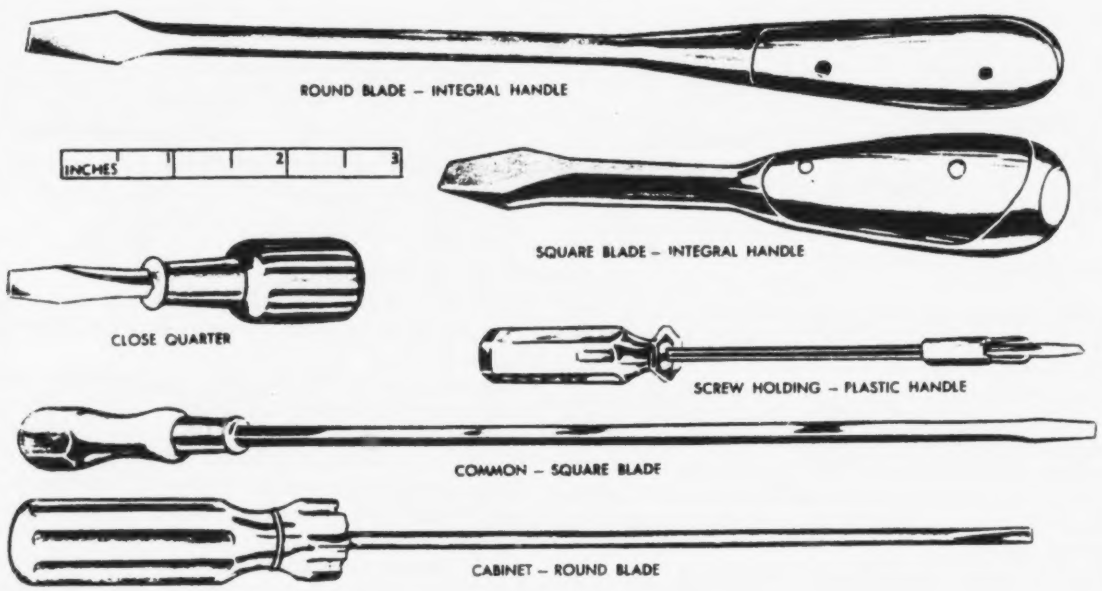

ROUND BLADE – INTEGRAL HANDLE
INCHES
1
2
3
SQUARE BLADE – INTEGRAL HANDLE
CLOSE QUARTER
SCREW HOLDING – PLASTIC HANDLE
COMMON – SQUARE BLADE
CABINET – ROUND BLADE

Figure 4–3. Standard screwdrivers.

2. What is the bumping hammer designed to do?

3. What is the primary purpose of a carpenter's hammer?

4. How are ball-peen hammers classified?

5. What is the round face of a riveting hammer used for?

6. What type of hammer is sometimes equipped with a brush?

7. What type of hammer would you use to drive bolts or drift pins?

8. The mallet is designed to do what type of work?

9. State the precautions to observe in the use of hammers and mallets?

10. What is the purpose of the carpenter's mallet?

11. What type of mallet is used to form or shape sheet metal?

### 236. State the use of various types of screwdrivers.

**Types of Screwdrivers.** Screwdrivers are made in various shapes and lengths to perform specific jobs. The size of a screwdriver (fig. 4-3) is indicated by the length of the blade (a 6-inch screwdriver has a 6-inch blade). The width and shape of blade tips vary from narrow parallel-sided tips to wide, tapered tips. Some screwdrivers have special tips for cross-slotted, recessed screws or bolts, and clutch-bit screws. Special screwdrivers are provided with a ratchet.

***Common screwdriver.*** The common screwdriver, shown in figure 4-4, has a round steel blade anchored in a wood or plastic handle. Some handles are integral; that is, the blade forms an integral part of some of the outside surface of the handle and is locked in place by rivets. Integral blade screwdrivers are used for heavy-duty work. The blade can be tapped with a hammer to seat the blade tip in rusty screws. Other common heavy-duty screwdrivers have square blades so that a wrench can be used to turn them. The screwdriver blade should be wide enough to go across the entire width of the screw slot, and the handle large enough for the work load.

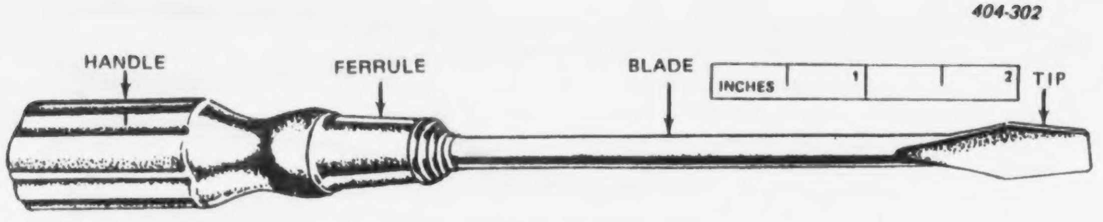


Figure 4-4. Common flat-tip screwdriver.

***Phillips screwdrivers (cross-tip).*** The tip of a Phillips screwdriver (fig. 4-5) is shaped like a cross so that is fits into Phillips-head screws. Phillips-head screws have two slots that cross at the center. These screwdrivers are made with four different sized tips. Size 1 will fit No. 4 and smaller size Phillips screws; size 2 will fit Nos. 5 to 9 inclusive; size 3 will fit Nos. 10 to 16 inclusive; and size 4 will fit No. 18 and larger size Phillips-head screws. Phillips screwdrivers also have different length blades ranging from 1 inch to 8 inches.

***Reed & Prince screwdrivers (cross-point).*** Reed & Prince screwdrivers are similar to the Phillips type; however, do not confuse them, for the tip is different, as shown in figure 4-5. These screwdrivers are issued in 3- to 8-inch sizes.

***Clutch-head screwdrivers.*** Clutch-head screwdrivers (fig. 4-5) are used to drive clutch-bit screws. These screws are commonly called butterfly or figure 8 screws and have recessed heads. The clutch-type screwdriver is issued in 3-, 4-, 5-, and 6-inch sizes.

***Offset screwdrivers.*** Offset screwdrivers (fig. 4-5) are designed to drive or remove screws that cannot be lined up with the axis of common screwdrivers or are located in tight corners. An offset screwdriver is usually made from a piece of steel, round or octagonal in shape, machined so that the end portion is at right angles to its longitudinal axis. They are made in a variety of sizes having different width tips. Some offset screwdrivers are made with two blades, one of different size at each end. A double-tip offset screwdriver has four blades.

***Ratchet screwdrivers.*** Ratchet screwdrivers (fig. 4-6) are used to drive or remove small screws rapidly. The spiral ratchet screwdriver automatically drives or removes screws. It can be adjusted to turn left or right or to lock to act as a common screwdriver. It has a knurled sleeve with a spiral chuck and a control locking device with three positions—right ratchet, left ratchet, and rigid. Another style of ratchet screwdriver has a knurled collar used for rotating the blade with your fingers. The spiral type has separate blades that insert in the chuck. The plain, common ratchet screwdriver is made with one integral blade.

***Jeweler's screwdrivers.*** Jeweler's screwdrivers (fig. 4-7) are made for driving and removing small screws. The tips range from 0.250 inch to 0.1406 inch wide. They have knurled handles and a swivel-end finger rest plate. The jeweler's screwdriver is used in disassembly and reassembly of camera parts and shutter.

**Care of Screwdrivers.** Use a screwdriver that has parallel sides and exactly fits the screw slot. A poor fitting screwdriver can damage the screw head, slip off the screw, and cause personal injury. If a tight screw with a damaged slot can be backed out partially, it is possible to remove it completely with a pair of pliers.

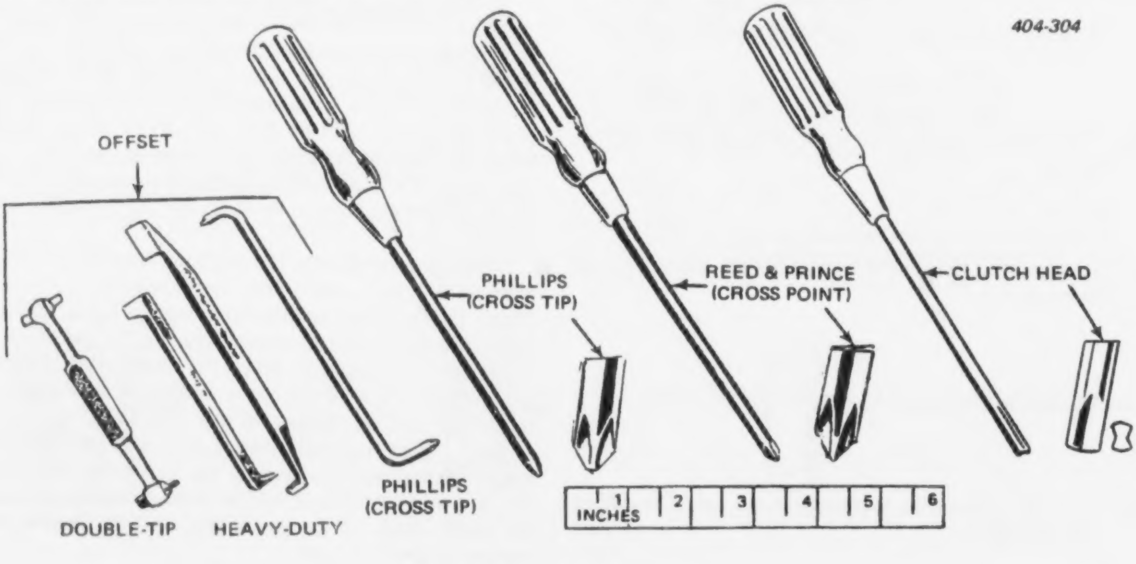


Figure 4-5. Special tipped screwdrivers.

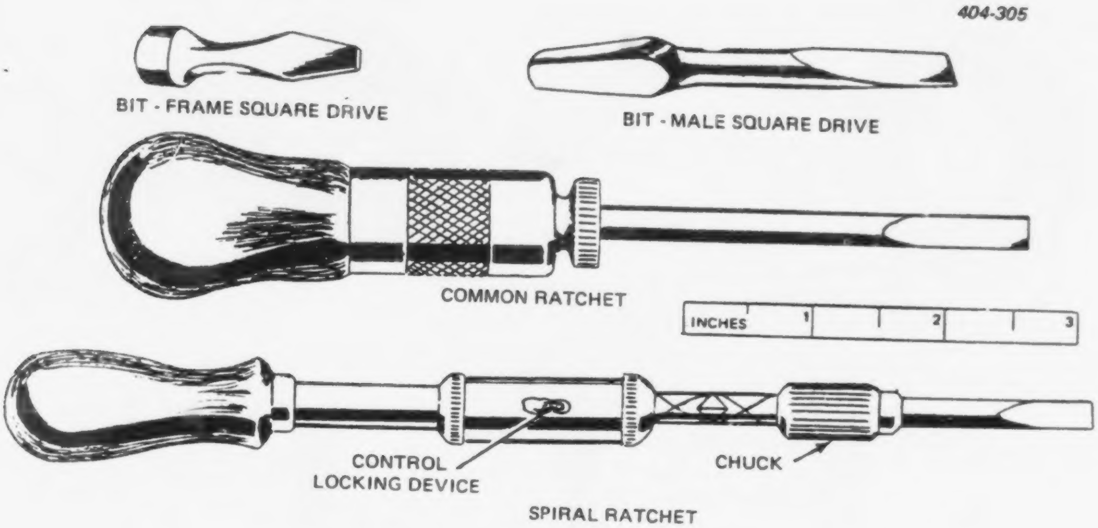


Figure 4–6. Ratchet screwdrivers and screwdriver bits.

When a screwdriver becomes nicked, or the edges become rounded, or when other damage occurs so that it does not fit a screw slot, it must be reground or filed. The sides must be parallel to keep the tool from lifting from the screw slot (fig. 4-8), and the tip must be square, at right angles to the sides and to the blade. If you are using a file, place the screwdriver in a vise. When using a grinder, adjust the rest to hold the screwdriver against the wheel to produce the desired shape, parallel or concave. Do not grind away more material than necessary to remove nicks or to square up the end. The driving face of the blade of a screwdriver is ground to fit the slotted head of the screw regardless of the slot configuration. After squaring the tip, grind both sides until the tip is of the required thickness. Dip the screwdriver into water frequently during grinding to prevent loss of temper by overheating. If the blade discolors (blue or yellow), the temper has been damaged. Retemper by heating about 1½ inches of blade to a cherry red with a torch. Immediately dip about 3/4 inch of the blade into clean cold water. Quickly rub the hardened end with aluminum oxide abrasive to brightened it. Watch the color creep back into the tip from the heated portion of the blade. When color becomes light blue, dip blade into water. The tip is now retempered and ready for use. Remember that screwdrivers are designed for one purpose only—to turn screws. They must never be used for any other task.

**Exercises (236):**

1. A common screwdriver with an integral blade is used for what type of work?
2. What size of Phillips screwdriver fits a No. 4 or smaller size Phillips screw?
3. The jeweler's screwdriver is used to remove what type of screws?
4. How wide should the blade of a common screwdriver be?
5. For what purpose is a screwdriver designed?

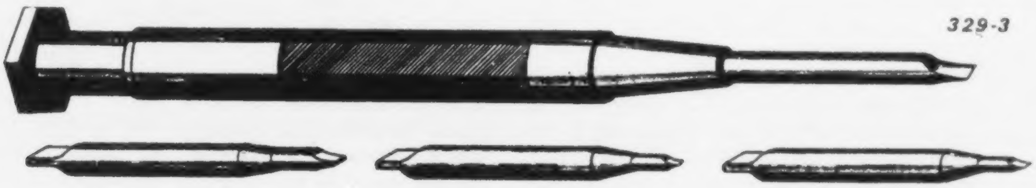


Figure 4–7. Jeweler's screwdriver.

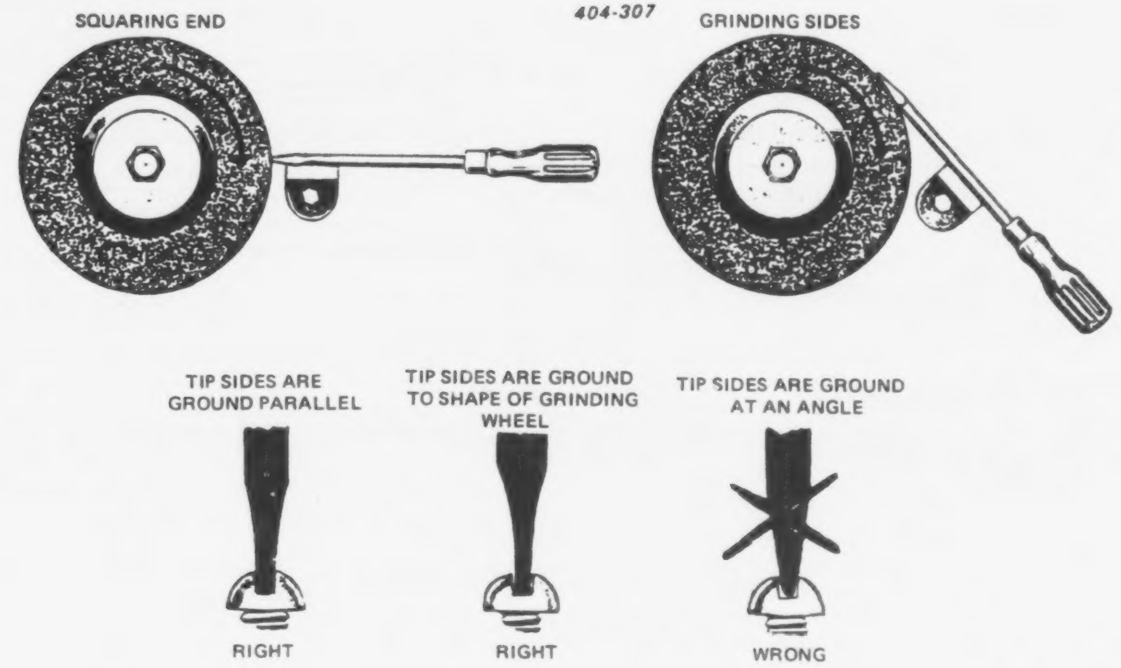

SQUARING END
404-307
GRINDING SIDES
TIP SIDES ARE GROUND PARALLEL
TIP SIDES ARE GROUND TO SHAPE OF GRINDING WHEEL
TIP SIDES ARE GROUND AT AN ANGLE
RIGHT
RIGHT
WRONG

Figure 4–8. Grinding screwdriver blade tip.

### 237. Specify the type of wrench to be used for specific tasks.

**Wrenches.** One of the important considerations about the use of wrenches is that you make the correct selection for the job to be done. If you use the wrong type of wrench, you may injure yourself and almost certainly will damage the work. A wrench that is too large can damage the work; if it is too small, the wrench may be damaged. Always make sure that the opening of the wrench fits the nut tightly. Using a wrench with too large an opening damages the corners of the nut and springs the jaw of the open end.

***Fixed-end wrenches.*** Fixed-end wrenches are designed to fit specific size nuts and bolts. There are numerous types in many sizes and shapes. In the following paragraphs we will cover the wrenches that are most commonly used in your career field.

*Open-end wrenches.* Various open-end wrenches are shown in figure 4-9. They are usually double-ended wrenches, although some have a single open end. These wrenches are forged from chrome-vanadium steel and are heat-treated. The size of the opening between the jaws determines the size of the open-end wrench. For example, a wrench with a 1/2-inch opening in one end and a 9/16-inch opening in the other end is called a 1/2 x 9/16 wrench. The size of each opening is usually stamped on the side of the wrench. The openings are from 0.005 inch to 0.015 inch larger than the size marked on the wrench so that they will easily slip on bolt heads or nuts of that size.

Open-end wrenches are made in many different sizes. Wrench sizes range upward in steps of 1/32 inch, starting with 5/32 inch up to 1¾ inches. The common open-end wrench is made with the ends at an angle of 10 to 23° to the body of the wrench so that the user can work in close quarters. Other special open-end wrenches have the ends at an angle of 45°, 60°, 75°, or 90°, or a combination of two angles. The length of the wrench is determined by the size of the opening, since the lever advantage of the wrench is proportional to its length; wrenches with larger openings are made longer and heavier to increase leverage and strength.

*Box wrenches.* Box wrenches (fig. 4-10) are so named because they completely surround or box the bolthead or nut. The opening in a box wrench contains 6 or 12 notches, called points, arranged in a circle. The box wrench is a safer tool than the open-end wrench, since it will not slip off the work. As little as one-twelfth of a turn can be taken at each stroke if necessary in close quarters. Box wrenches may be offset, or the box end may be offset. Box wrenches are available in the same sizes as are open-end wrenches and usually have two openings, one opening 1/16 inch larger than the other. Some openings are 1/32 or 1/8 inch larger than the other. A ratchet box wrench usually has two 12-point openings and is not automatically reversible. However, it can be turned around to do both tightening and loosening operations. Being of sturdy, thin construction, these wrenches are convenient for working in limited spaces. Ratchet box wrenches are issued in four sizes, ranging from 3/8- and 7/16-inch openings to 3/4- and 7/8-inch openings.

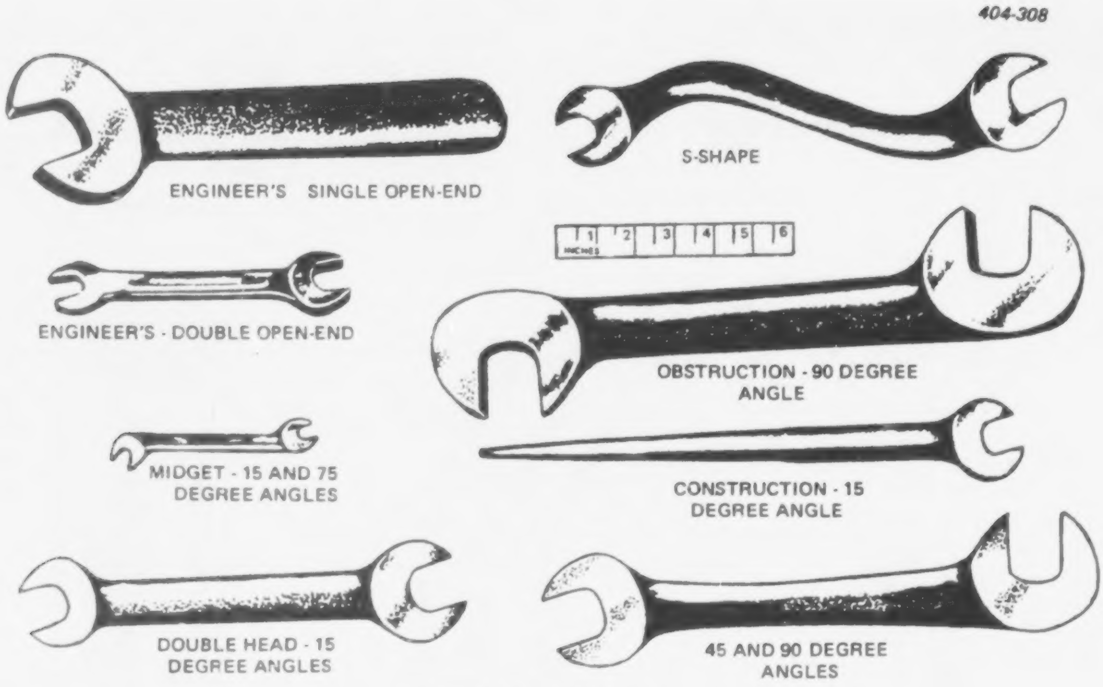

404-308
ENGINEER'S SINGLE OPEN-END
S-SHAPE
INCHES 1 2 3 4 5 6
ENGINEER'S - DOUBLE OPEN-END
OBSTRUCTION - 90 DEGREE ANGLE
MIDGET - 15 AND 75 DEGREE ANGLES
CONSTRUCTION - 15 DEGREE ANGLE
DOUBLE HEAD - 15 DEGREE ANGLES
45 AND 90 DEGREE ANGLES

Figure 4–9. Open-end wrenches.

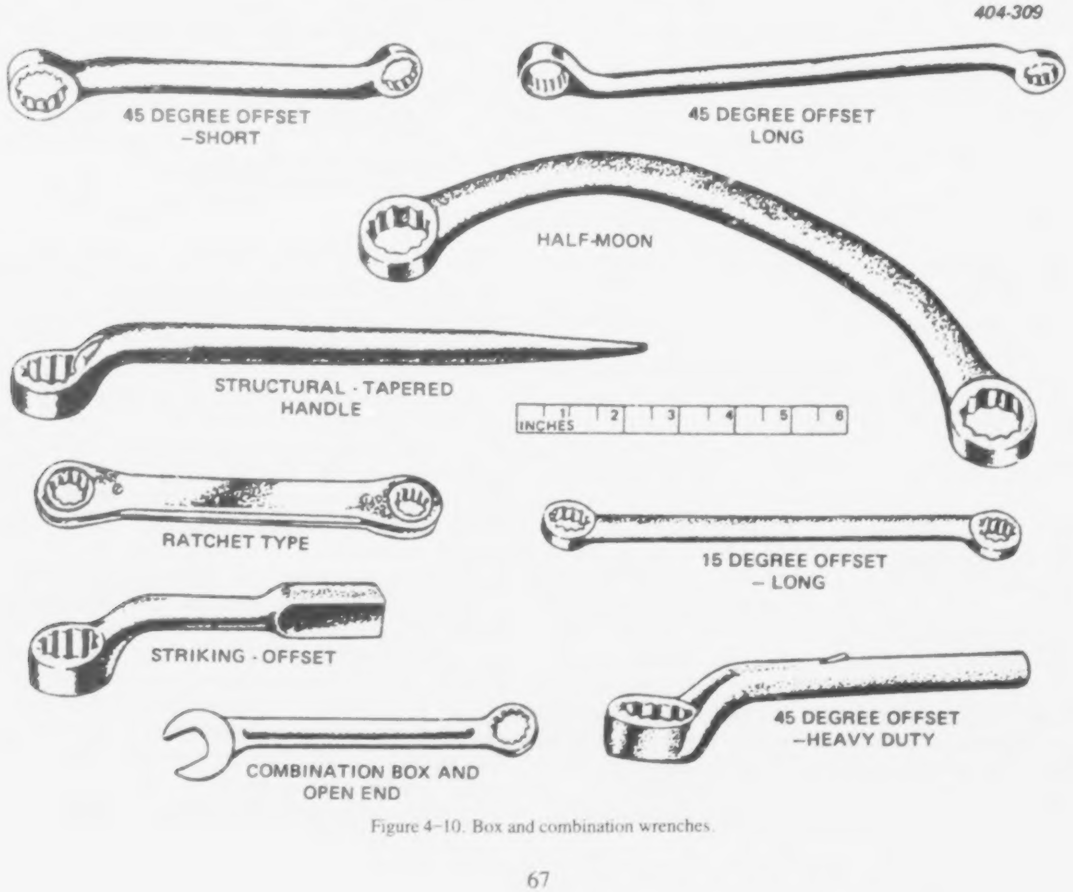


Figure 4–10. Box and combination wrenches.

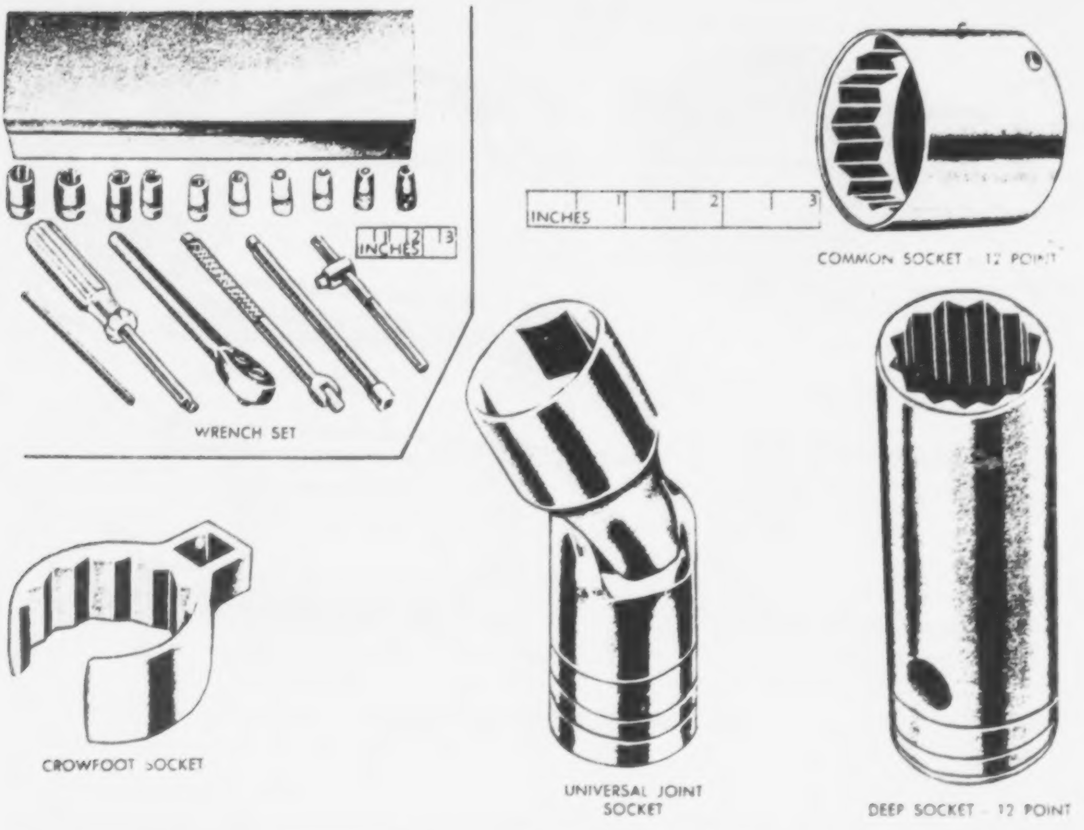


Figure 4–11. Socket and crowfoot wrench.

*Combination open and box wrenches.* Combination wrenches (fig. 4-10) have one open end and a box wrench at the other end. Combination wrenches are made with many combinations of sizes, offsets, and angles.

*Socket wrenches.* The common socket wrench is boxlike and is made as a detachable socket (fig. 4-11) to fit various types of handles. A socket wrench set (fig. 4-11) usually consists of various sized sockets, a ratchet (fig. 4-12), a sliding bar tee, a speeder, a speed tee, a ratchet adapter, a nut spinner, a 3/8-inch drive handle, and extensions. Socket wrenches have two openings, a square hole that fits the handles and a circular hole notched sides to fit the bolt, screw head, or nut to be turned. The square hole is made 1/4, 3/8, 1/2, 3/4, or 1 inch in diameter; each must be driven with the matching drive or speeder handle. The notched opening may have 6, 8, or 12, points. Socket wrenches are the fastest wrenches to use, since the ratchet handle permits the socket to remain on the nut or bolt and the handle does not have to be removed from the socket for turning. Socket wrenches are sized from 5/32 to 3 ⅛ inches in steps of 32ds, 16ths, or 8ths of an inch.

*Special socket wrenches.* Some socket wrenches are not detachable and are of the one-piece construction, such as the four-way socket wrench and the 90° offset handle shown in figure 4-13. Other socket wrenches are of the screwdriver type, having a six-pointed or a square socket. These may be straight or offset and have a T-type or regular screwdriver handle. Two types of stud remover sockets are available that are used with any 3/4-inch square drive socket wrench handle. One type has an eccentric cam that grips soft or hardened studs. The driving shank extends through both sides of the housing to provide a bearing surface on each side of the cam and to prevent binding. The cam type has a capacity of 1/4 to 3/4 inch. The heavy-duty, wrench-type stud remover socket works on the wedge principle and takes a positive grip that can be released only when the tool is turned in the reverse direction. Two sizes of steel wedges are included with the socket. This type has a capacity of 9/16 to 1 inch.

*Crowfeet wrenches.* A crowfoot wrench (fig. 4-11) has an open end in the box containing notches and a square hole that fits the handle. They are used in conjunction with socket wrench handles having a 3/8- or 1/2-inch square drive. They range in size from 3/8 to 2½ inches.

*Setscrew and hollow-head capscrew wrenches.* Most setscrews and hollow-head capscrews have a hexagon (six-sided) socket. The commonly known key (Allen) wrench (fig. 4-14) is L-shaped, made of tool steel, and has a hexagonal or square section to fit these screws. Splined setscrew wrenches (fig. 4-14) are made of round stock with ends to fit little flutes or splines in headless setscrews. A hollow-head capscrew set is also supplied. This set has detachable sockets that are used with the accompaning handles.

*Plug wrenches.* A plug wrench (fig. 4-14) is a straight bar having a hexagon or square shape and is available in a range of sizes from 3/8 to 1 inch in width. They are usually 2 inches long. Plug wrenches are also made to fit drain plugs of transmissions, differentials, and all types of gear cases. The multiple plug wrench shown in figure 4-14 is a combination type, having ends of several different sizes and shapes. Most plug wrenches are made for a specific size plug. There are single-end plug wrenches that range in size from 3/16 to 11/16 inch with a hexagonal or square end. Double-end plug wrenches with square ends are issued with 3/8- and 1/2-inch plugs and 3/8- and 3/4-inch plugs. These wrenches are normally 8 to 12 inches long. Socket plug wrenches (fig. 4-14) have a 1/2-inch square drive to be used with socket wrench handles.

*Flare nut wrenches.* A flare nut wrench (fig. 4-14) is a notched, thin-walled, split box wrench especially designed to fit over nuts in very close places. It is ideal for tightening brass tube flare nuts. It grips the nut on five sides; it does not slip and mar the nut. Flare nut wrenches are of 12-point design and have either a single or double end. Openings range in size from 3/4 to 1⅝ inches.

***Adjustable wrenches.*** Adjustable wrenches differ from fixed-end wrenches in that the size of the opening is adjustable to fit more than one size nut or bolt. The adjustable wrench should be used when the correct size fixed-end wrench is not available.

*Single open-end wrench.* The single open-end adjustable wrench (fig. 4-15) is similar in shape to the fixed-end, nonadjustable open-end wrench, but has one adjustable jaw and one stationary jaw. The adjustable-end wrenches have up to 2⅞-inch jaw openings and are up to 24 inches long. A knurled nut is rotated to bring the movable jaw up to fit the nut or bolthead.

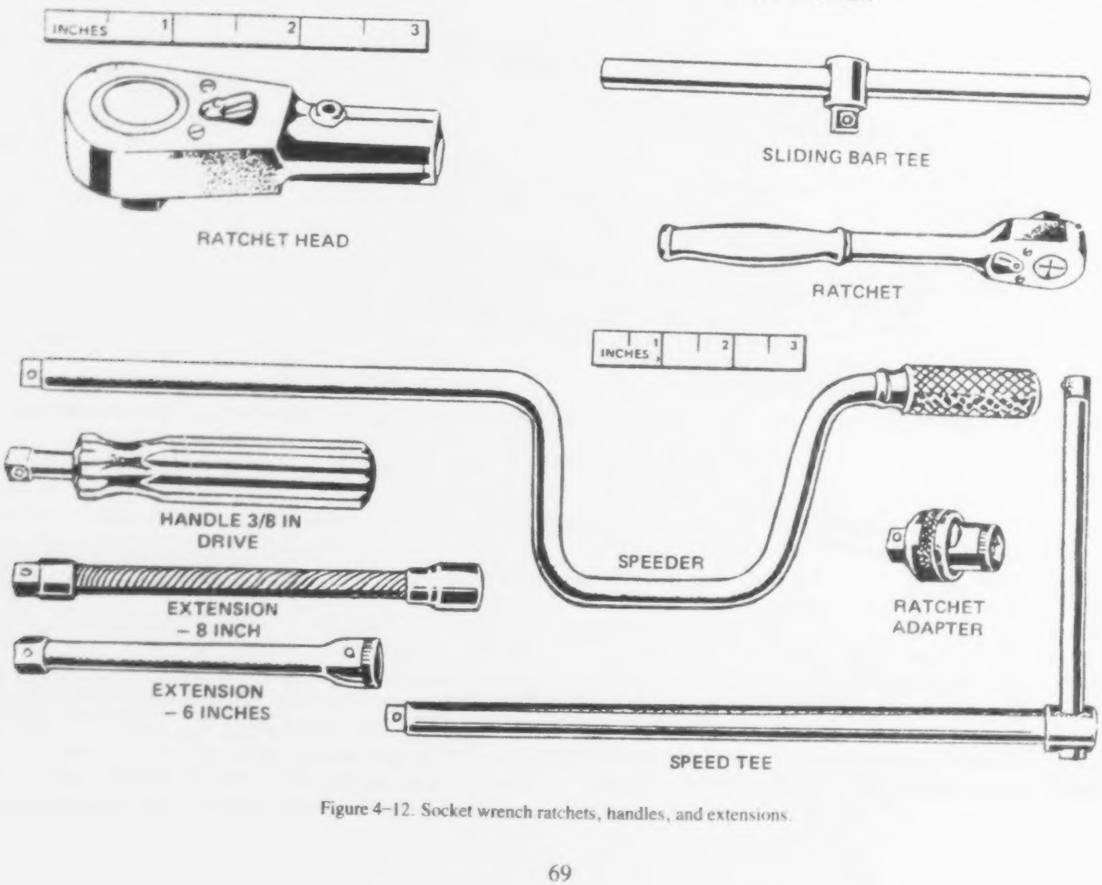


Figure 4–12. Socket wrench ratchets, handles, and extensions.

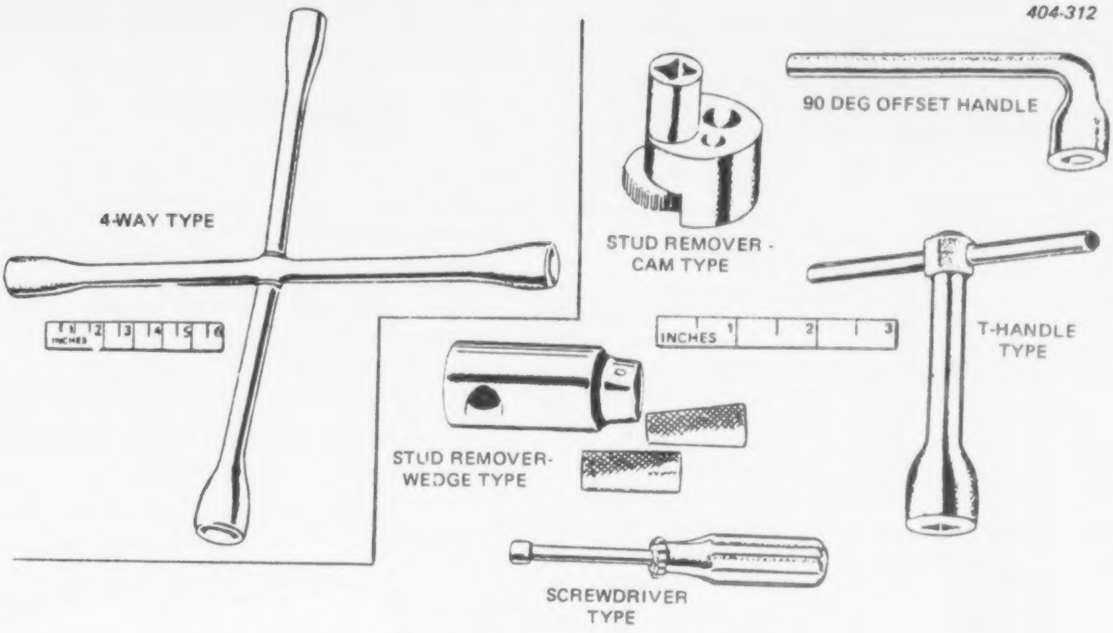


Figure 4–13. Special socket wrenches.

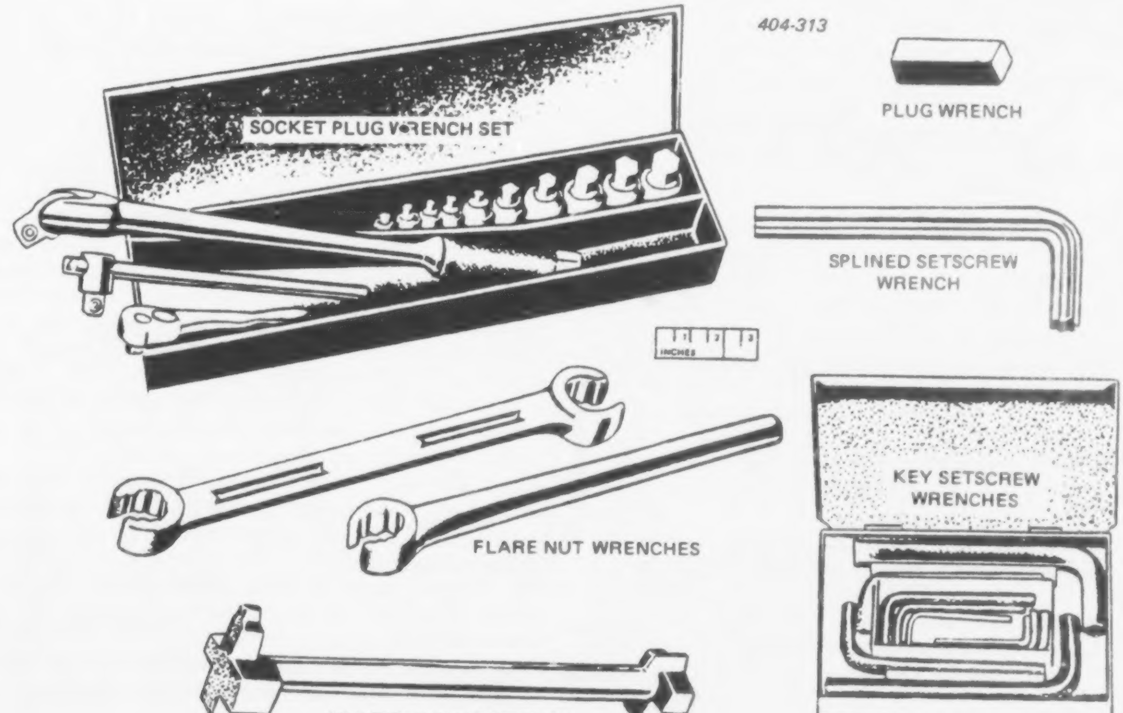


Figure 4–14. Setscrew, plug, and flare nut wrenches.

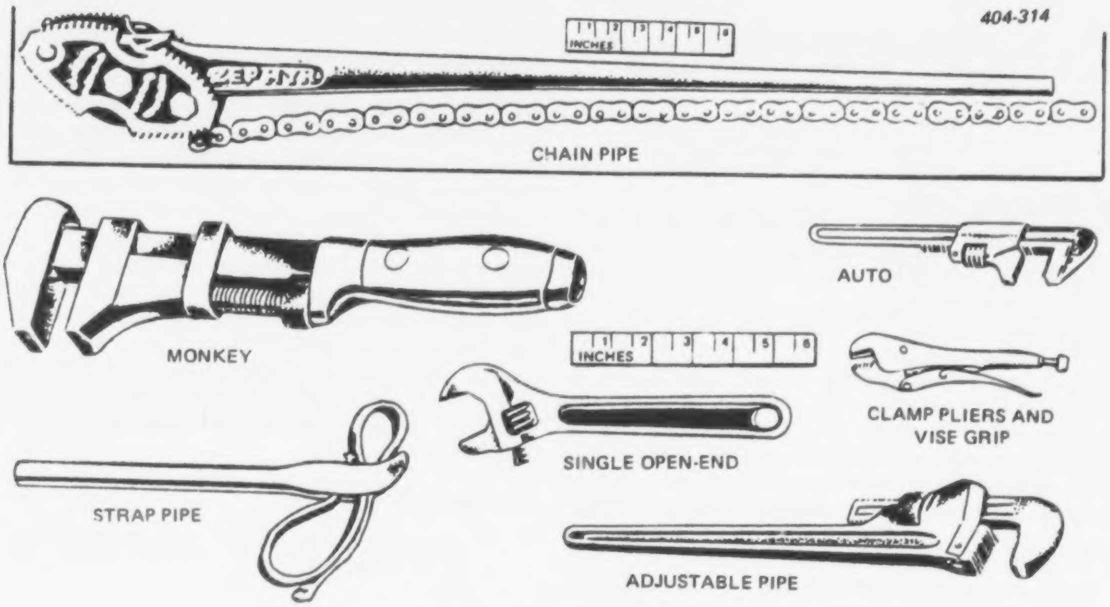


Figure 4–15. Adjustable wrenches.

*Auto and monkey wrenches*. The auto and monkey wrenches (fig. 4-15) are similar in design. They are of sturdy construction and are made to fit a wide range of nuts and bolts. They are designed principally for turning odd-sized nuts or bolts which the open-end, box, or socket wrenches will not fit and when work requires a sturdy wrench. They are supplied in several sizes, from 5 to 21 inches long.

*Clamp pliers and vise grip wrench*. The clamp pliers and vise grip wrench (fig. 4-15) has one movable jaw and one stationary jaw. The movable jaw is adjusted by an adjusting screw in the base of the stationary jaw handle. The movable jaw can be clamped around anut or bolt after setting the jaw to the desired size. This type wrench is issued in two sizes; 1⅛-inch jaw opening capacity and 7 inches long, and 1¼-inch capacity and 10 inches long.

*Pipe wrenches*. There are three basic types of pipe wrenches: the adjustable wrench, the strap wrench, and the chain wrench. They are all used to connect or break pipe joints or to turn cylindrical parts.

*Adjustable pipe wrench*. The adjustable pipe wrench (fig. 4-15) has two jaws that are not parallel. The outer jaw, which is adjustable, is made with a small amount of play which provides a tight grip on the pipe when the wrench is turned in the direction of the movable jaw. This is the only wrench that will take a bite on round objects. The jaw always leaves marks on the work and should never be used on nuts or bolts unless the corners have been rounded so that you cannot turn them with another type of wrench.

*Strap pipe wrench*. The strap wrench (fig. 4-15) is also used to turn cylindrical parts, but will not mar the work because the strap serves as jaws. These wrenches are issued in a 1/8- to 2-inch pipe capacity size and a 1- to 5-inch pipe capacity size.

*Adjustable chain pipe wrench*. The adjustable chain pipe wrench (fig. 4-15) is a long-handled tool with a single jaw and a length of chain that fits around the pipe to be turned and over the connection at the end of the jaw. The chain acts as the other jaw. It is used for gripping rough pipe work on large diameter pipe. These wrenches range in size from 35 to 64 inches long and have a pipe capacity from 3/4 to 12 inches.

***Torque wrenches.*** A torque wrench (fig. 4-16) is used for work requiring a particular force (torque) to tighten bolts, nuts, capscrews, etc., to a desired degree of pressure. A dial or scale calibrated in footpounds indicates the degree of torque placed on the work.

The three most commonly used torque wrenches are the deflecting beam, dial indicating, and micrometer setting types. When using the deflecting beam and the dial-indicating torque wrenches, the torque is read visually on a dial or scale mounted on the handle of the wrench.

To use the micrometer setting type, unlock the grip and adjust the handle to the desired setting on the micrometer-type scale; then relock the grip. Install the required socket or adapter to the square drive of the handle. Place the wrench assembly on the nut or bolt and pull in the desired direction with a smooth, steady motion. (A fast or jerky motion results in an improperly torqued unit.) When the torque applied reaches the torque value that is indicated on the handle setting, the handle automatically releases or "breaks" and moves freely for a short distance. The release and free travel is easily felt, so there is no doubt the torquing process is complete.

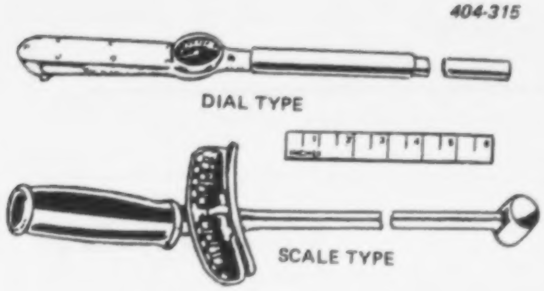


Figure 4–16. Torque wrenches.

To assure getting the correct amount on the fasteners, all torque handles must be tested at the end of the established calibration period or more often if usage indicates it.

Observe the following precautions when using torque wrenches:

*a*. Do not use the torque wrench as a hammer.

*b*. When using the micrometer setting type, do not move the setting handle below the lowest torque setting, but place it at its lowest calibrated setting prior to returning it to storage.

*c*. Do not use the torque wrench to apply a greater amount of torque than its rated capacity.

*d*. Do not use the torque wrench to break loose bolts that have been previously tightened.

*e*. Never store a torque wrench in a toolbox or in an area where it may be damaged.

***Spanner wrenches.*** The two basic types of spanner wrenches are the hook type and the pin type. Both the hook and pin types come in adjustable end and fixed end. For our discussion we will cover them as fixed spanner wrenches and adjustable wrenches.

*Fixed spanner wrenches*. Fixed spanner wrenches (fig. 4-17) are used to turn flush type and recessed retaining rings, cover plates, plugs, hose couplings, and parts that have holes or slots for insertion of the pins and lugs. Each of this type of spanner wrench is designed for a particular job.

*Adjustable spanner wrenches*. An adjustable face spanner wrench (fig. 4-17) has two legs joined together with a pivot pin. The legs can be opened and closed, allowing the pins at the end of the legs to fit the various distances between holes found in many types of cover plates and plugs. It is also used to remove a lens' retaining ring. Another type of adjustable spanner wrench is shaped like a hook and is called an adjustable hook spanner wrench. The position of the hook can be adjusted to fit different size couplings and other parts.

**Exercises (237):**

1. What wrench would you use to remove a retaining ring on a lens barrel?

2. What wrench or screwdriver would you use to tighten a headless screw on a shaft?

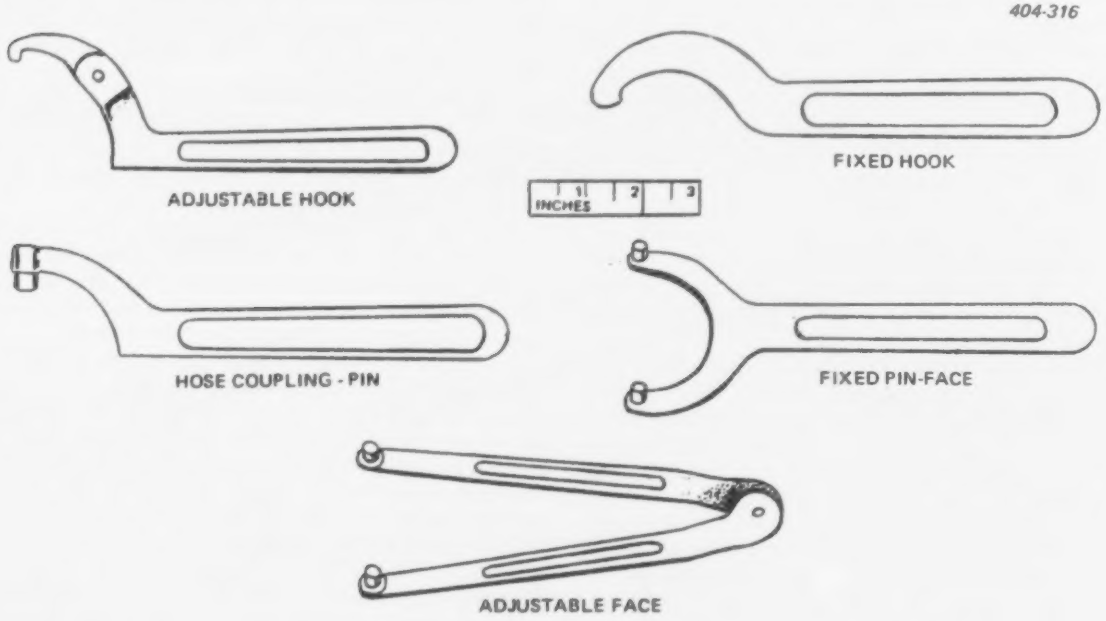


Figure 4–17. Spanner wrenches.

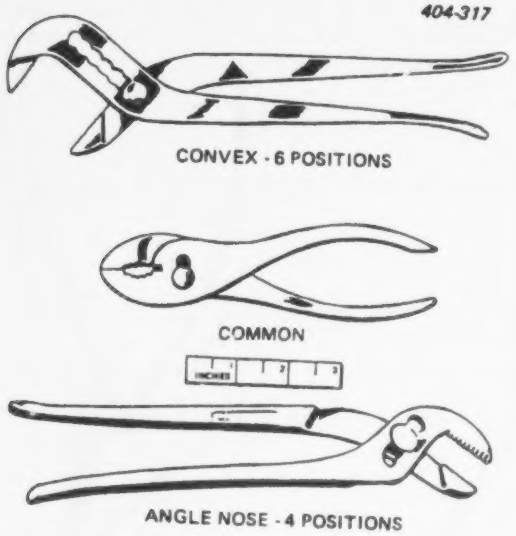


Figure 4-18. Slip joint combination pliers.

3. What type of wrench would you use to loosen a nut in an obscure place?

4. What type of wrench would be used to rotate round stock?

5. What type of wrench is used to tighten bolts, nuts, etc., to a desired degree of pressure?

## 238. Specify types of pliers to use for a given task.

**Pliers and Tongs.** Pliers are used for gripping, cutting, bending, forming, or holding work, and special jobs. Tongs look like long-handled pliers and are used mainly for holding or handling hot pieces of metal to be forged. Pliers basically consist of a pair of jaws designed for a specific purpose, a pivot or hinge, and a pair of handles. They are made in many shapes and sizes to handle a variety of jobs. The size is determined by the overall length, which usually is 5 to 10 inches.

***Slip-joint combination pliers.*** The slip-joint combination pliers, shown in figure 4-18, are most commonly used to hold or bend wires. Some have a short cutting edge near the hinge for cutting wire. The slip joint permits adjustments and wider opening of the jaws. The jaws have teeth for gripping.

***Diagonal cutting pliers.*** Diagonal cutting pliers (fig. 4-19) have short jaws with the cutting edges at a slight angle. They are used for cutting soft wire and stock and for removing cotter pins. They are also used for cutting cotter pins to a desired length and for spreading the ends after the pin is inserted through a hole.

***Parallel-jaw, flat, and roundnose pliers.*** These pliers, shown in figure 4-20, are used to bend or form metal into various shapes and to work in limited quarters.

***Special-purpose pliers.*** Refer to figure 4-21. Some pliers are made for special jobs, such as brake spring pliers, glass holding and breaking pliers, ignition, battery terminal, brake key, and snap ring pliers.

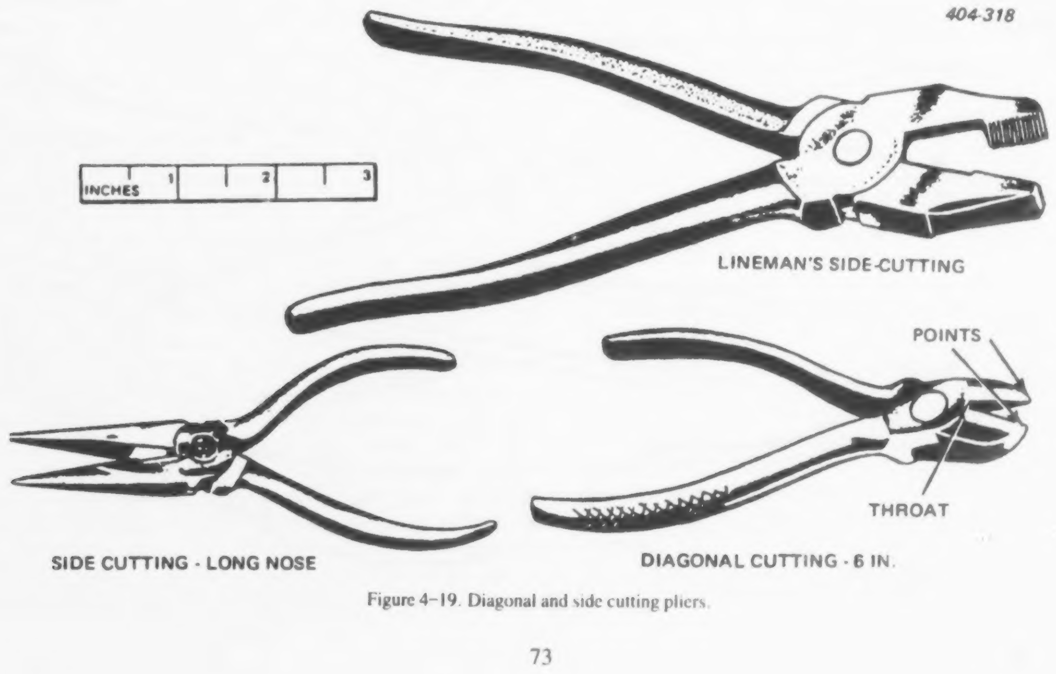


Figure 4-19. Diagonal and side cutting pliers.

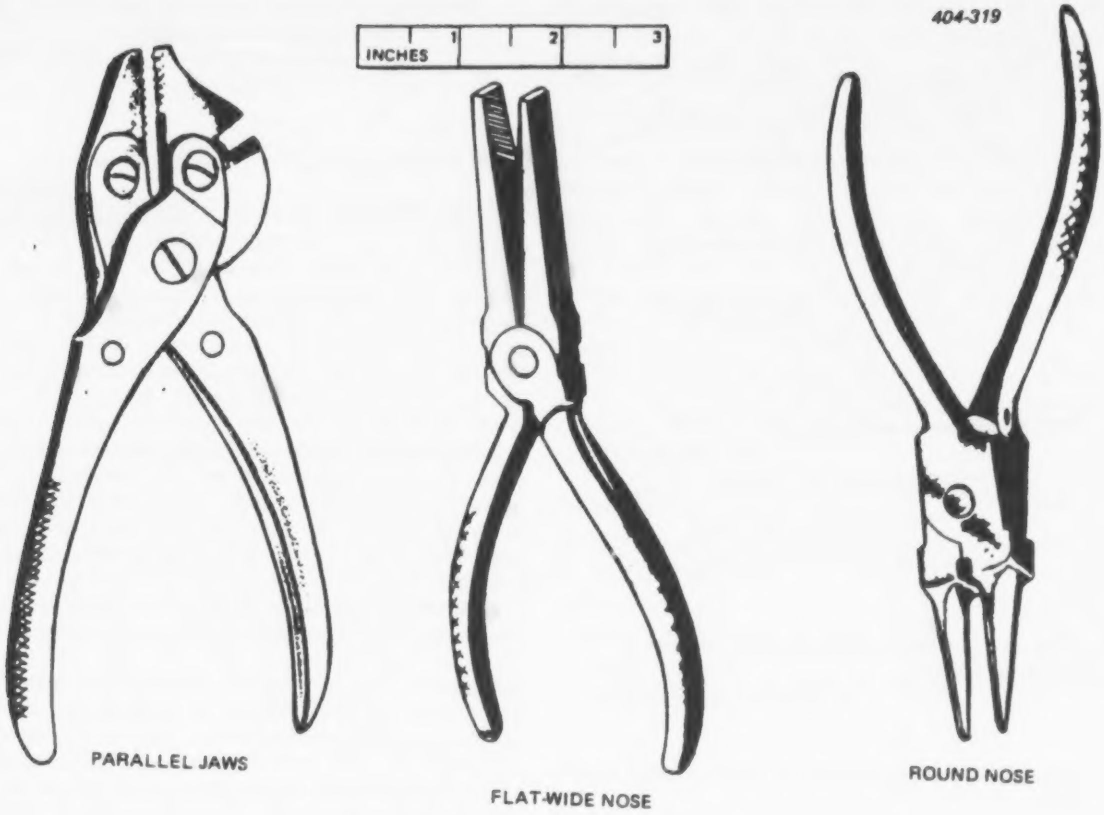


Figure 4–20. Parallel jaws, flat, and round nose pliers.

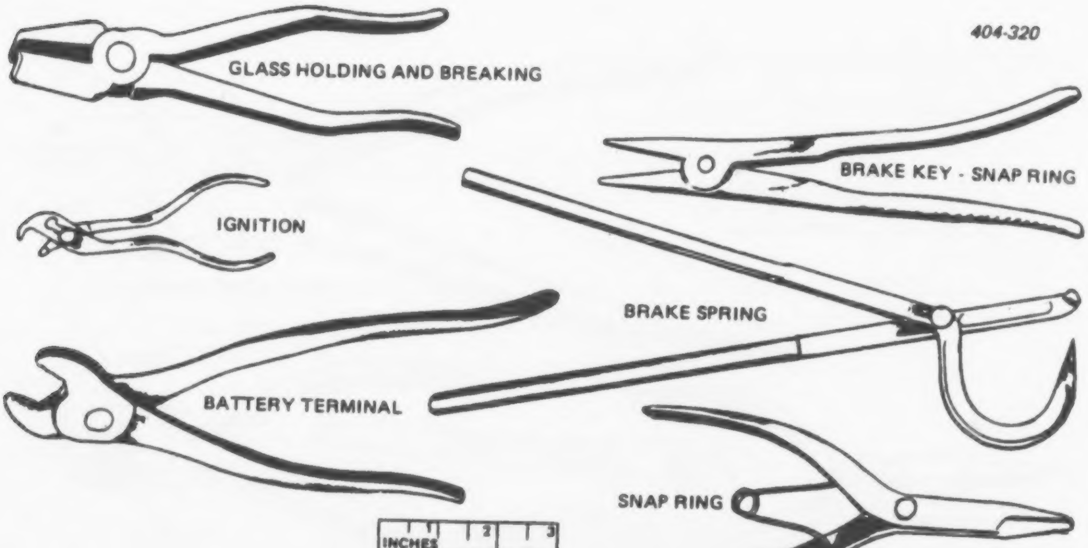


Figure 4–21. Special purpose pliers.

***Tongs.*** The tongs differ in their use. The blacksmith's tongs are used for picking up and holding hot metal. The straight-lip, flat-jaw tongs are used to hold bearings while setting them in place.

**Exercises (238):**

1. What type of pliers would you use to bend or form metal?

2. What type of pliers would you use to bend wire?

3. To remove a cotter pin, what type of pliers would you use?

### 239. State the purpose for which tweezers are designed and the precautions to observe when using them.

**Tweezers.** Tweezers are used for holding or handling small parts. Shapes and sizes vary, depending upon their use. They are normally made from steel or nonmagnetic material such as brass or bronze. Some tweezers have locking devices to lock the jaws in the closed position. The tips may be curved, straight, or at various angles to the main body. (Cutting tweezers are also available for cutting very light, very small work.)

Tweezers are used to handle parts that are so small that the fingers could not possibly manipulate them. They are also used to handle small parts that would be damaged if allowed to come in contact with the perspiration of the hand. As a specialist, you must develop a "feel" for using the tweezers. A fine sense of touch is needed to handle very small parts. Too little pressure causes the part to slip from the jaws of the tweezers. Too much pressure causes the tips of the tweezers to damage the part or to bow outward. The part sometimes is pushed out of the jaws and flipped some distance from the immediate working area. Some camera equipment has parts as small and delicate as watch parts. Use tweezers in the disassembly and reassembly of this equipment. Remember that tweezers are actually tiny, delicate pliers made for holding, manipulating, and bending tiny parts. Don't use tweezers for pliers or pliers for tweezers. The tool, the part, or both may be damaged.

Tweezers are only as effective as the condition of the jaws. They require constant care, inspection under powerful magnification, and meticulous maintenance. The jaw-holding surfaces must be parallel when closed on the part. When closed with nothing between them, the jaws should meet at the tip and be in perfect alignment when observed from any direction. Always check the working surfaces of the tweezers before use. If the jaws are not properly aligned, shaped, or surfaced, condition them before use. A small amount of bending or hand honing on a hard Arkansas stone will usually return the tip of the tweezers to excellent condition. Tweezers perform best if they have only sufficient spring to move the jaws apart when the slight amount of finger pressure required to keep them together is released. Store tweezers so that they are not damaged by rust, corrosion, or bending. Clean the points of very fine tweezer tips with cleaning fluid. Stick them into cork or similar material when they are not in use, to protect you as well as the tools.

**Exercises (239):**

1. For what purpose are tweezers designed?

2. List three precautions associated with using tweezers.

### 240. Specify factors to consider for file selection and precautions to take for file care.

**Files.** Files are tools designed specifically for removing material. File nomenclature is shown in figure 4-22. These tools are made in many shapes and grades of coarseness to suit a wide variety of jobs. General classifications of files are according to (1) the cross-sectional shape, (2) the type of cut, and (3) the length. Shapes of files are flat, square, round, half-round, triangular, etc. Files with one row of parallel teeth are called single-cut files. Those with one row of teeth crossing another row of teeth (and forming a crisscross pattern) are called double-cut files. Cuts are also classified as to their different degrees of coarseness. Some sample descriptive terms are coarse, bastard, second-cut, smooth, and dead smooth.

Always choose the correct file for the job. When choosing a file, consider these factors:

*a*. The kind of material to be filed.
*b*. The shape of the cut to be made.
*c*. The amount of material to be removed.
*d*. The type of finish desired.

If there is a large amount of material to remove, start with a coarse file, progress to a file that is less coarse, and then finish with a smooth file. When using the file, remember the following important points:

*a*. Never use a file without a handle! The end of the tang is sharp and might easily be driven into the palm of your hand.

*b*. Clamp the work securely in a vise.

*c*. Hold the broad end of the file with the handle against the palm of your right hand with your thumb on top.

*d*. Hole the narrow end of the file in your left hand with your fingers curled under it.

*e*. Hold the file straight.

*f*. File slowly—no more than 30 to 40 strokes per minute.

*g*. Remove all pressure on the backstroke.

*h*. Use only enough pressure to keep the file cutting.

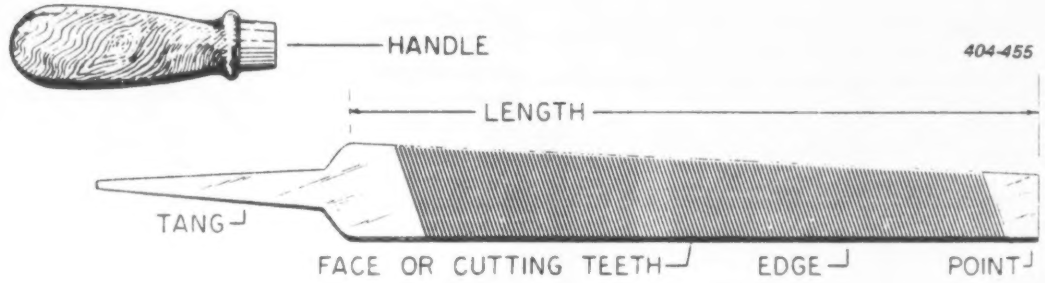


Figure 4-22. File nomenclature.

*i.* Push a single-cut file sideways across the work to produce a very smooth surface. (Use a clean, smooth file for this type of work.)

Always clean a file that has become clogged with material. If you do not, it will damage the work. Use a file cleaner (bristle brush and steel-wire file card) and a file pick. This equipment and procedure for use are shown in figure 4-23.

You should remember the following cautions applicable to caring for files:

*a.* Never use a lubricant on the file.

*b.* Keep files dry. (Files will rust, and rust on the teeth of a file will dull its cutting edges.)

*c.* Never throw files together in a toolbox.

*d.* Never put files where they may contact another tool.

*e.* Never use a file for any task other than filing.

**Exercises (240):**

1. You have a large amount of material to be removed. What type of file would you start with?

2. What factors should you consider when choosing a file?

3. Why should files be kept clean?

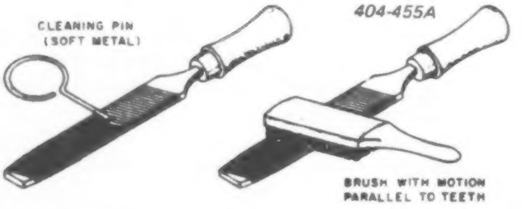

CLEANING PIN (SOFT METAL)
404-455A
BRUSH WITH MOTION PARALLEL TO TEETH

Figure 4-23. Cleaning of the file, equipment and procedure.

4. What precautions should be followed with respect to file lubrication?

5. Why should you keep files dry?

**241. State the precautions that should be exercised when using chisels.**

**Metalworking Chisels.** Chisels designed for working with metal are forged-steel instruments with specially shaped and hardened cutting edges. They are used to dress, shape, or cut metal. The metalworking chisel is a timesaving tool. It will remove excess metal rapidly and will make the work ready for final finishing with a file if used properly. The following precautions are important for you to remember:

*a.* Always wear safety goggles while using a metal working chisel. Be sure that you also protect your fellow workers from flying chips.

*b.* Hold the point of the chisel at the spot where the cutting is to be done. (The angle of the cutting face with respect to the metal determines the depth of the cut.)

*c.* Keep the hand holding the chisel relaxed.

*d.* Grip the handle of the hammer near the end and swing it with a free, easy motion.

*e.* Keep hand, hammer, and chisel free of oil.

*f.* Always regrind the head of the chisel to the correct shape when it becomes mushroomed.

*g.* Always keep the chisel points ground to a good cutting edge.

**Exercises (241):**

1. Of the precautions given for using metalworking chisels, which is the most important?

### 242. Select the correct type of metal-cutting saw for a given task.

**Metal-Cutting Saws.** The hacksaw and the jeweler's saw portrayed in figure 4-24 are two common saws used for cutting metal. They consist of two basic parts: the frame and the blade.

Let's consider the hacksaw first. When a hacksaw blade is properly placed in the frame, its teeth point away from the handle, and thus it cuts only on the forward stroke. The blade may be rotated on its longitudinal axis, within the frame, to permit working in close quarters (where the frame would normally prevent sawing). Hacksaw blades are made so that the teeth have a variety of degrees of coarseness. A blade with few teeth per inch should be used on soft metals—such as aluminum, copper, brass, and bronze—and also on thick surfaces. The blade with many teeth per inch should be used on hard metals, such as machine steel, and on thin materials.

The following precautions are important:

*a.* Be sure that the blade is stretched tightly in the frame.

*b.* See that the work is clamped securely.

*c.* Use only enough downward pressure on the saw to keep the teeth biting into the metal on the forward stroke.

*d.* Relieve all downward pressure on the return stroke.

*e.* Hold the saw so that an absolute minimum of two teeth are in contact with the work.

*f.* Clamp very thin material between two pieces of wood so you cut both the wood and the metal simultaneously.

*g.* Regulate the number of strokes per minute to about 20 to 40 for metals of average hardness.

*h.* Don't apply twisting motion to a hacksaw blade.

*i.* Lubrication on the hacksaw blade is not necessary.

Install the blade of the jeweler's saw in the frame so the teeth point toward the handle. Support the work on a solid surface with a V-notch cut in it. (This will support the work except on one side and yet will leave room to operate the saw.) The saw is used handle down in a vertical position with the cutting action taking place on the downward stroke. If the direction of cutting is to be changed, the sawing action must be continued as the direction of the cut is changed. Otherwise you will break the saw blade. Do not twist or force the blade at any time. (Jeweler's saw blades are easily broken by excessive force or by a twisting action.) Make sure that the saw travels up and down vertically and that the pressure is applied to the downward stroke only. If properly used, the jeweler's saw blade should last until the teeth become dull and no longer cut satisfactorily. Broken blades indicate improper use of the saw.

Jeweler's saw blades come in various grades of coarseness, and the same general rules should be applied for their use as are applied for hacksaw blades.

Saw blades, like other cutting tools, are easily dulled. They also represent a constant threat to the safety of the user. Store them in such a way that both you and the teeth are protected. Handle them with care since the saw teeth are hard and brittle and may be easily dulled, damaged, or broken.

**Exercises (242):**

1. If you must cut machine steel, do you use a metal cutting saw with few teeth or one with many teeth?

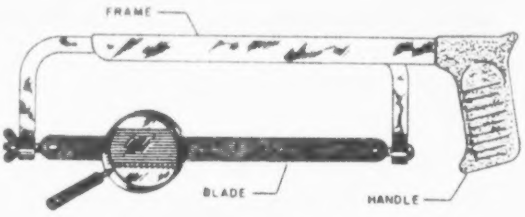
2. What is the direction of the saw action of the jeweler's saw?

### 243. State the purposes and uses of nonmagnetic and insulated tools.

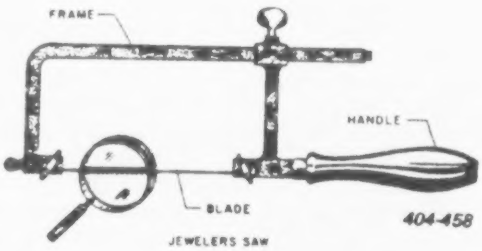
**Nonmagnetic Tools.** Tools made of nonmagnetic materials are available through normal supply channels. They are used for performing specific maintenance functions on certain classes of equipment or components. These expensive tools are normally made of beryllium-copper or plastic, are not as rugged as steel tools, and are much more easily damaged.

Restricting the use of the nonmagnetic tools to the purpose for which they are intended increases their value to the technician. Use of these tools for general maintenance would allow them to transfer metal or other foreign particles into electronic equipment. The gears and bearings in sensor systems are easily fouled by small particles of dust or metal.

Nonmagnetic tools should also be used in tuning RF circuits that are susceptible to frequency change resulting from the new magnetic fields (or the distortion of the existing magnetic fields). Many slug-tuned IF circuits involve this potential trouble.



HACKSAW



JEWELERS SAW

Figure 4-24. Metal cutting saws.

Good general maintenance practice involves wiping the tools before use and again after use. This is especially advisable in the case of nonmagnetic tools. A lint-free cloth dampened with a suitable cleaning solvent may be used for this purpose.

Nonmagnetic metals are usually softer than steel, so use of these tools for general maintenance could also damage the tools.

**Insulated Tools.** Safety considerations require use of insulated tools whenever the danger of electrical shock or short circuit exists. Many types of tools are available in insulated form directly through supply channels at little or no additional cost. These tools should be obtained and used whenever available. However, many types of insulated tools are not readily available, or are available only at considerable added expense. If essential, these tools should be procured or conventional tools may be modified. Insulated sleeving may be put on the handles of pliers and wrenches and on the shanks of screwdrivers. Tools modified in this manner should be used only for low voltage circuits because of the limitations of the insulating materials. For higher voltage uses, special insulating handles are available for many of the common types of tools.

Sometimes, it is necessary to use tools that are made of insulating material, rather than merely having an insulating handle. In these instances, the tools should be requisitioned through normal supply channels, if possible. If they are not available through normal supply channels, they may be purchased on the open market through procurement.

**Exercises (243):**

1. When should nonmagnetic tools be used?

2. What type of tool would you use when the danger of electrical shock or short circuit exists?

3. What is good maintenance practice before and after using nonmagnetic tools?

4. What type of tool would you use in tuning RF circuits?

### 244. State the purpose and use of the taper pin insertion and removal tool.

**Taper Pin Insertion and Removal Tool.** The taper pin insertion and removal tool (fig. 4-25) is used to remove and insert taper pins from system connectors. The insertion tool has a calibrated driving spring, a calibrated pull test spring, a taper pin captive key, and a taper pin removal feature.

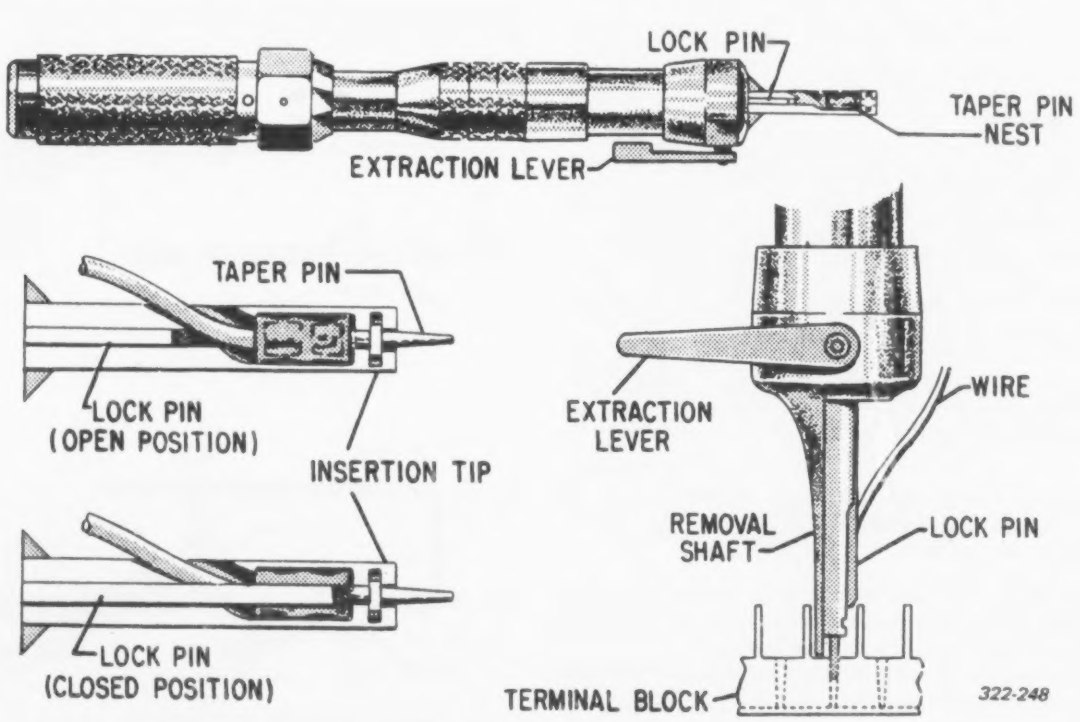


Figure 4-25. Taper pin insertion and removal tool.

The driving spring adjusts to apply the proper driving impact to the pin. The pull test spring adjusts to apply the correct pull force on the pin to check for proper pin insertion. The captive key ensures that each taper pin has a 100-percent pull test before the tool is disengaged from the pin. The removal or extraction lever is rotated to remove the taper pin from the terminal block socket.

In order to maintain the reliability of the system, it is imperative that the taper pin be properly inserted into the terminal block sockets. Pushing the pins into the sockets with the fingers or pliers does not make them stay—they must be driven in with the insertion tool. The tool must be calibrated to ensure that the proper pressures are used. When inserting the taper pins, hold the insertion tool at right angles (90°) to the terminal block and push straight toward the terminal block without twisting the tool. The pins are very sensitive to twists, which could cause a faulty connection or a broken pin. Always replace bent or broken pins. If you follow correct installation procedures, a taper pin may be installed and removed as many as 25 times before a replacement is necessary. A properly installed taper pin will pass the pull test of the insertion tool.

Three different sizes of taper pins are used to terminate wires from size 16 through size 22. The sizes are identified by color coding of the insulating sleeves. A crimping tool is used to attach the taper pin to the wire.

**Exercises (244):**

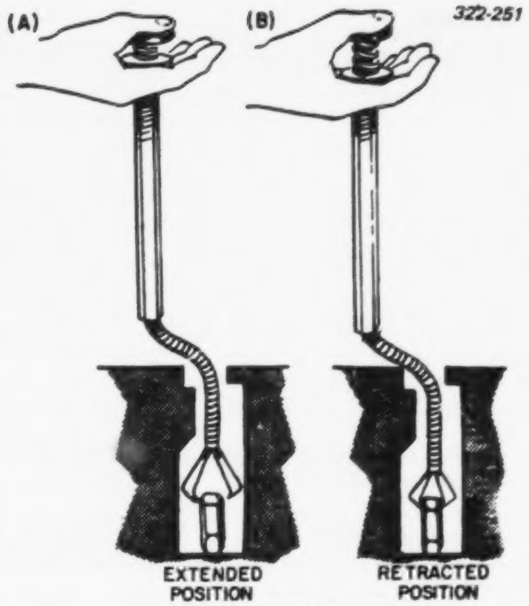
1. State the purpose of the taper pin insertion and removal tool.

2. What tool is used to attach a taper pin to a wire?

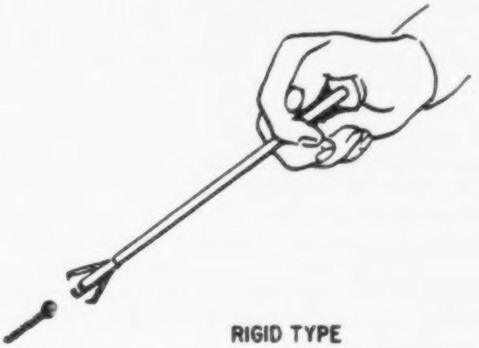
### 245. State the purpose of mechanical fingers and inspection mirrors.

**Mechanical Fingers.** One of the biggest problems you may encounter when working on equipment in the shop or on location is dropping screws, nuts, or other small articles into places where you cannot retrieve them.

Small articles that fall into places where they cannot be reached by hand may be retrieved with mechanical fingers. This tool is also used when starting nuts or bolts in areas that are difficult to reach. Mechanical fingers (fig. 4-26) have a tube containing flat springs that extend from the end of the tube to form clawlike fingers. The springs are attached to a rod that extends from the outer end of the tube. A plate is attached to the end of the tube, and a similar plate to be pressed by the thumb is attached to the end of the rod. A coil spring placed around the rod between the two plates holds them apart and retracts the fingers into the tube. With the bottom plate grasped between the fingers and enough thumb pressure applied to the top plate to compress the spring, the tool fingers extend from the tube in a grasping position. When the thumb pressure is released, the tool fingers retract into the tube as far as the object they hold will allow. Thus, enough pressure is applied on the object to hold it securely. Some mechanical fingers have a flexible end on the tube to permit their use in close quarters or around obstructions.



FLEXIBLE TYPE



RIGID TYPE

Figure 4-26. Mechanical fingers.

NOTE: Mechanical fingers should not be used as a substitute for wrenches or pliers. The fingers are made of thin sheet metal and can be easily damaged by overloading.

**Inspection Mirrors.** There are several types of inspection mirrors available for use in aircraft maintenance. The mirror is issued in a variety of sizes and may be round or rectangular. The mirror is connected to the end of a rod and may be fixed or adjustable.

The inspection mirror aids in making detailed inspection where the human eye cannot directly see the inspection area. By angling the mirror, and with the aid of a flashlight, it is possible to inspect required areas.

**Exercises (245):**

1. Mechanical fingers are used for what two purposes in maintenance?

2. What is the reason for not using mechanical fingers as a substitute for wrenches or pliers?

3. What is the purpose of inspection mirrors?

### 246. Cite the purpose for which each of three types of punches is designed.

**Punches.** Any solid punch (fig. 4-27) is basically one of three general types: the pin punch, the prick punch, and the drift punch.

***Pin punch.*** The regular pin punch has a straight shaft and is used to remove a straight pin or taper pin after it has been loosened with a starting punch, which can take more stress. A pin punch is also used to loosen a pin if its small end is below the surface of the item pinned. The starting punch is a modified pin punch. It is a sturdy punch with a tapered shaft used to loosen or to set straight pins or taper pins.

***Prick punch.*** The prick punch is used for making small indentations on layout lines, timing marks, etc. It is primarily used for marking. The center punch is a modification of the prick punch and is used in metal work to make indentations that serve as a guide for a twist drill. The angle of its point matches the angle of the drill point.

***Drift punch.*** The drift punch, often called a drift pin, is used for aligning holes in two pieces to simplify inserting bolts, rivets, pins, etc.

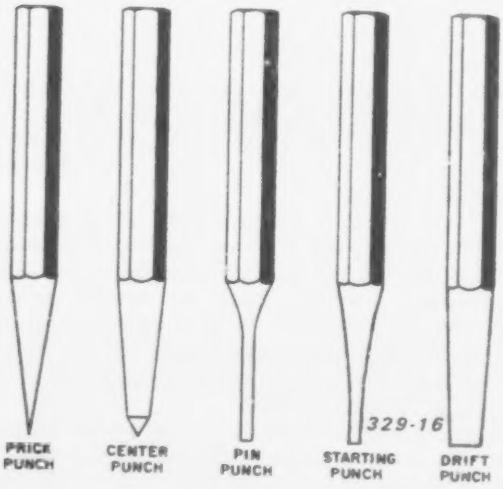


Figure 4-27. Solid punches.

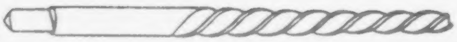


Figure 4-28. Screw extractor.

Use a punch solely for the purpose for which it was designed. The only maintenance required is occasional refinishing of the tip and head. Keep pointed punches sharp. Dress a driving punch so that it has a perfectly flat tip. If the head of a punch becomes mushroomed, dress it to the correct shape.

**Exercises (246):**

1. For what purpose is the pin punch designed?

2. For what purpose is the prick punch designed?

3. For what purpose is the drift punch designed?

4. What maintenance is required for punches?

### 247. State how a screw extractor is used.

**Screw Extractor.** The screw extractor, commonly called an easy-out (fig. 4-28), is used for removing screws, bolts, studs, or pipes that have broken off inside a hole. Its shank is similar to a tap and the body has a hardened, left-handed, tapered, spiral thread formed by flutes in the body.

To remove a broken screw from its hole, select an extractor and a drill bit that are slightly smaller in diameter than the solid screw. Drill a hole centered in the screw and insert the extractor. With a tap wrench, turn the extractor counterclockwise into the hole in the screw. As the extractor is turned, it locks into the broken screw and backs it out of its hole. To release the easy-out from the broken screw, hold the broken piece securely and turn the easy-out clockwise. In a few instances, the screw may be hollow. In this case, of course, you do not need to drill a hole. The same procedure is used for broken bolts and studs.

You have not finished the job until the tools are cleaned and put away. Clean the foreign material, if any, from the spiral thread of the extractor and store the extractor according to rules that apply to storing other small cutting tools.

**Exercises (247):**

1. For what purpose is a screw extractor used?

2. What must you do in order to remove a broken screw with a screw extractor?

3. Which direction must you turn the extractor to release it after removing the broken screw?

## 4-2. Power tools

The care and use of power tools is usually a greater problem than hand tools. If you can learn to use the power tools that are available in the field, it will save you time and you will do a better job. You have more than likely used most of the power tools in the field. There are some power tools that are larger and more complex to use. For a complete description and operating instructions for power tools that you are not familiar with, you should consult Air Force manuals or commercial manuals. In the following sections we will discuss some nomenclature, as well as some of the more important points to consider when operating power tools. Special care must be taken in the maintenance of power tools. They must be lubricated in accordance with instructions. In tropical, polar, or excessively damp climates, care must be taken to prevent rust, fungus, and corrosion.

### 248. State the procedure for operating an electric hand drill.

**Electric Hand Drill.** The electric hand drill is similar in its basic function to a manually operated hand drill. The significant difference is that the electric motor will turn the chuck and twist drill. You still must support the drill and apply the pressure that causes the drill bit to cut. Electric hand drills vary in size, and if the appropriate size drill is used, the power-driven hand drill is capable of drilling holes in metal up to about 1 inch in diameter. Most electric hand drills are provided with self-centering, three-jaw chucks and have pistol-grip handles. Some of the larger sizes have additional handles that permit you to stabilize the drills with both hands and to apply pressure with both hands.

Always make certain that the hole you drill in metal does not exceed the maximum drill size that will be accepted by the chuck. (A twist drill twice the size of the capacity of the chuck may be used in any power drill when drilling holes in wood.) Although large bits are specially made with small shanks, such bits may overload the motor or the reduction gears when you are drilling metal. If you must use a large twist drill with a small shank, make sure the power drill itself is capable of doing the work without being damaged.

Place the point of the twist drill in a center-punched hole with adequate cutting lubricant and start drilling. Make certain that the drill is held perpendicular to the work and apply only enough pressure for the cutting edges of the bit to remove metal. Frequent application of a cutting lubricant during the drilling process is recommended. (Cutting lubricants are discussed under "drill presses.") When the tip of the twist drill begins to break through the metal, relax the pressure you are applying. This is necessary to keep the twist drill from catching on the rough metal burr that is formed as the hole being cut on the far side of the metal gradually thins out the remaining metal. Such a burr can catch on the bit and spin the power drill from your grasp. This problem can frequently be minimized by direct-contact backing of the material being drilled with another piece of scrap metal. (The two metal pieces must be held together firmly.)

Keep the chuck clean and free from bits of metal and dirt. Remove all burrs from a drill bit shank before putting it in the chuck, since such burrs may cause the twist drill to turn out of alignment with the spindle. Most electric hand drills manufactured today have bearings that are prelubricated for their lifetime. Make certain that this particular type of drill is not lubricated, or the oil may get into the windings of the motor. If a drill does require oiling, do this at the intervals recommended in the manufacturer's instructions and limit the amount of oil to the specific amount designated. Always remember that too much oil can ruin any electrical motor.

**Exercises (248):**

1. What is the maximum size twist drill that should be used to drill metal when using an electric hand drill?

2. How can you keep the drill from spinning from your grasp when drilling through metal?

### 249. State the procedures and precautions to observe when operating a drill press.

**Drill Presses.** The vertical spindle, hand-feed drill press (fig. 4-29) is the one most often used in maintenance shops. It can be used as a floor or bench model and is suitable for light drilling tasks. An electric motor with a belt drive provides the power to the spindle. The speed of the motor shaft is governed by the size of the pulleys. The part of the drill press that turns the drill bit is the spindle.

On some drill presses, a tapered hole in the lower end of the spindle will accept a tapered shank drill or a self-centering Jacobs tapered shank chuck. A hand lever moves the spindle downward toward the work. The spindle is spring loaded to keep it in a raised position when it is not in use. A drill press is used to hold the work on the working table so the work being drilled will not move around. This could cause an accident and also ruin the work. Always make sure that the work is held tight, for if a burr causes the

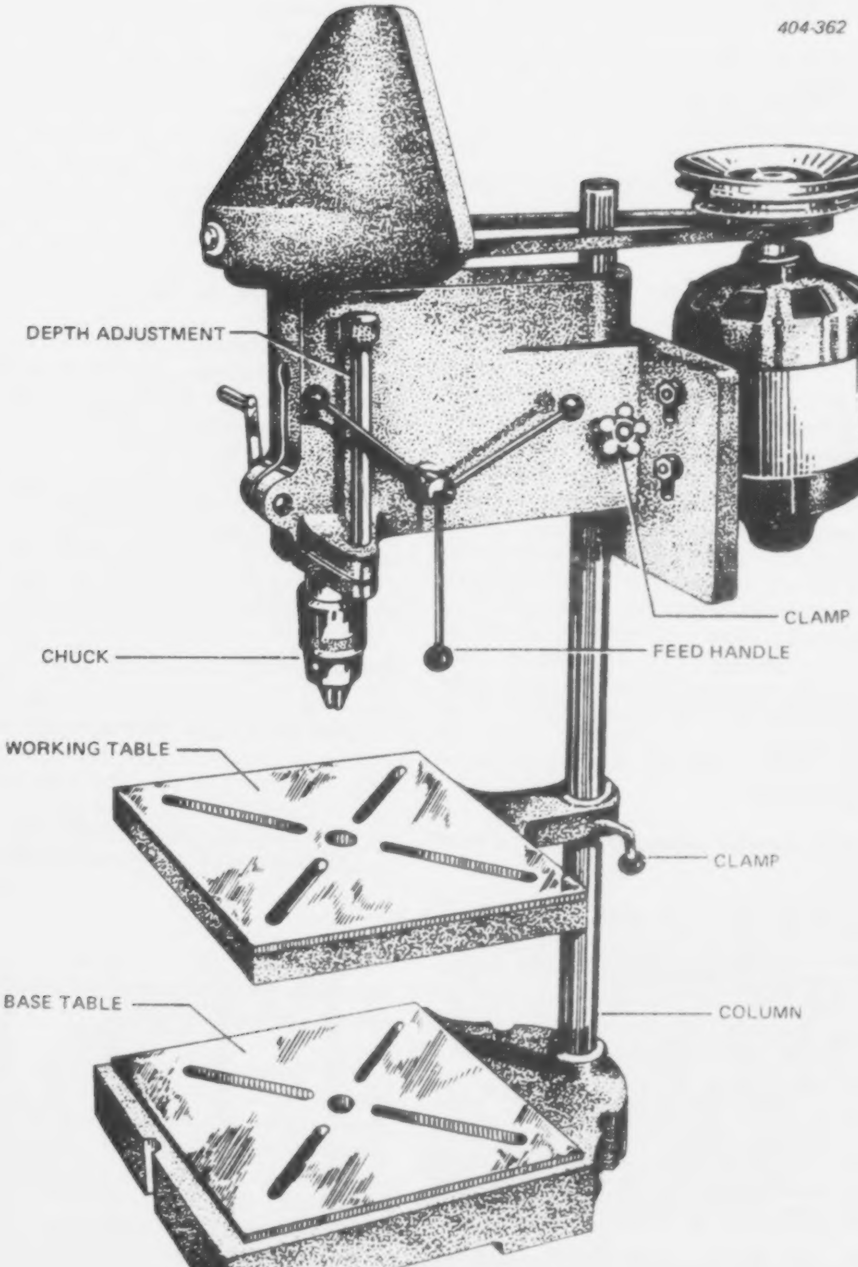


Figure 4-29. Drill press.

bit to turn the work, it will spin around at the speed of the motor.

When you insert the drill bit into the chuck, make sure that it is all the way in and the chuck is very tight on the bit. Lower the spindle with the feed handle until it is centered with the punched spot on the work. When the drill starts to cut, apply a light pressure. Be very careful not to apply too much pressure, or you will overheat the work and the drill.

Lubricants are used in drilling operations. They are called coolants. Some of the common lubricants used are:

- Turpentine.
- Kerosene.
- Water and soap.
- Lard oil.
- Cutting oil.

The lubricants are applied to the drill and to the work to keep the drill from overheating. Usually the coolants must be applied by hand. Some drill presses have automatic coolant devices that apply the coolant at all times.

Be very careful when operating the drill press. Do not wear loose-fitting clothes. Wear goggles to protect your eyes from burrs. Burrs are very hot and could cause the loss of an eye. When you are drilling, do not force the drill. Apply a light pressure to cut, and then move the bit up. This will allow the metal to be removed from the hole and the bit, and allow the motor to keep the fast rpm needed to make a clean cut.

Exercises (249):

1. Name the two types of drill presses used.

2. What is used to prevent burning the bit?

3. Why should you wear goggles?

**250. Associate the parts of a lathe with the appropriate description.**

**Lathe.** The lathe is a useful power tool and may be found in some precision photo system maintenance shops. There are two types used in photo shops—jewelers' lathes or general-purpose lathes. You will find a lathe in the 430B maintenance van.

Although the lathe is a useful tool for cutting or shaping metal parts, it takes some training to set up and operate the lathe without damage to you or the lathe. This discussion will not attempt to train you to operate the lathe, but we will discuss the different parts of the lathe and some of the work that can be done on it.

The lathe (fig. 4-30) is a mechanical device used to shape material. This lathe is the most common type used in the preparation of small parts. Almost all lathes have certain parts that are similar in name and function, regardless of make. These parts are bed, headstock, tailstock, carriage, and lead screw.

***Bed.*** The bed is the foundation on which the lathe is built and supported. It is a single iron casting that is rigidly built. It runs the length of the lathe. Along its upper surface are precision surfaces called ways that are machined and hand-scraped to a high degree of accuracy. The ways align the headstock and tailstock and guide the carriage.

***Headstock.*** The headstock contains the driving unit, the spindle, and the change gears. The driving unit transmits the power from the motor to the spindle. The spindle supports one end of the material being shaped, supplies the power to rotate the material, and through the change gears, rotates the lead screw.

***Tailstock.*** The tailstock supports the other end of the material being shaped by means of the dead center. It can also serve as a mounting for various tools when the work can be supported by the spindle.

***Carriage.*** The carriage is the movable portion that slides along the ways. It consists of the saddle and apron. The saddle supports the compound rest, which provides the cutting tool with a solid support. The rest can be adjusted to the position you desire. The apron contains the mechanism and the controls for moving the carriage, engaging the crossfeeds, and engaging and disengaging the lead screw for thread cutting.

***Lead screw.*** The lead screw drives the power carriage feeds and regulates the carriage travel for thread cutting. The lead screw is rotated by changing gears in the headstock.

***Common Chucks.*** There are five common types of chucks that are used for different setups. They are used when the work cannot be set up between the centers, but must be mounted on one of the chucks described below.

***Four-jaw chuck.*** This chuck can be used to hold square, round, and irregular shapes.

***Three-jaw chuck.*** The three-jaw chuck automatically centers round or hexagonal work to an accuracy of 0.003 inch.

***Hollow Jacobs chuck.*** This chuck is for holding small diameter bars, rods, or tubes. It is also convenient when these bars, rods, or tubes must be passed through the headstock.

***Drill chuck.*** The drill chuck can be mounted in either headstock or tailstock, and is used for holding straight shank drills, reamers, and taps.

***Collet chuck.*** This chuck has three jaws and is closed by drawing it into a tapered sleeve. Except for three or four openings, it completely surrounds the work.

As we mentioned before, the lathe is driven by a powerful motor. For an untrained person it is a dangerous tool. At high-speed settings a lathe can throw chips, tools, and other debris quite some distance and at a very high speed. The following are some precautions to observe when working with the lathe.

- Never wear loose clothing.
- When a problem is encountered for any reason, shut off the machine until the problem has been solved.
- Keep your hands away from all moving parts.

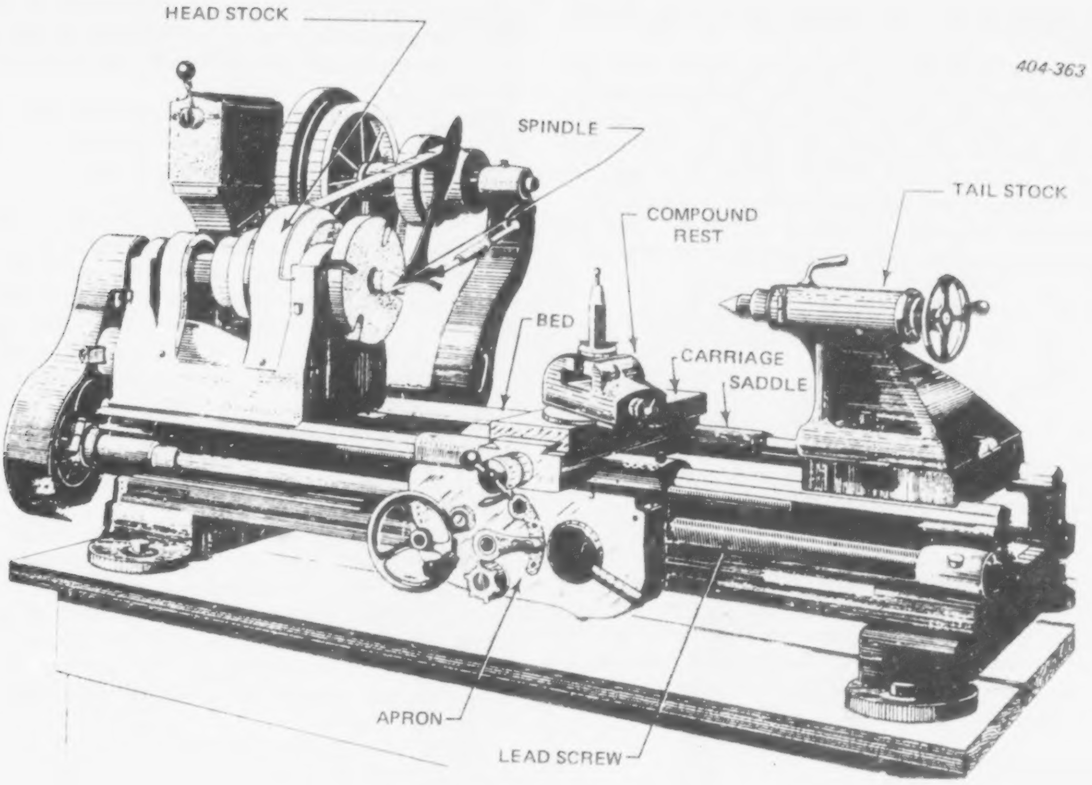


Figure 4-30. Metal working lathe.

- Never take your eyes off the machine. It requires your undivided attention.
- Do not use your bare hand to remove shavings, chips, or other forms of metal.
- Know the operation of your lathe before you operate it.

**Exercises (250):**

1. Match the part in column A with the description in column B.

*Column A*

____ (1) Headstock.
____ (2) Tailstock.
____ (3) Lead screw.
____ (4) Carriage.
____ (5) Bed.
____ (6) Common chucks.

*Column B*

a. Precision surfaces.
b. Drive unit, spindle, and change gears.
c. Supports material being shaped.
d. Movable portion which slides on the ways.
e. Regulates the carriage travel.
f. Used for different setups.

### 251. State the purpose and operating procedures for a bench grinder.

**Bench Grinder.** Bench grinders are used for reshaping and sharpening chisels, drills, hatchets, and other similar small handtools.

The bench grinder (fig. 4-31) consists of five components. They are (1) a clamp, (2) a rest, (3) an abrasive wheel, (4) a handcrank, and (5) an encased gearing assembly. The clamp is used for fastening the grinder to a working surface. The rest supports tools that are being ground. It is adjustable and may be moved from side to side. The abrasive wheel may be changed depending upon the type of metal being ground.

CAUTIONS. Eye protection should be worn when using a bench grinder. Never use a cracked wheel. Before using, inspect the grinder and the abrasive wheel for cracks or breaks on exposed surfaces. Check the abrasive wheel by tapping it lightly with a mallet. A ringing sound indicates that the wheel is satisfactory; a dull sound indicates that the wheel may be cracked. Before using, ensure that the grinder is securely mounted. The hand crank grinder requires two people for operation. The user must use both hands to hold the tool to the wheel; another person is required to turn the hand crank. When using an electrically operated grinder the second person is not required. The tool that you are grinding should be supported on the rest, and moved back and forth across the abrasive wheel face to be sure of an evenly ground surface. Hold tools being shaped firmly so they will not catch in abrasive wheel and cause injury. Ensure that all outside surfaces of the grinder are wiped free of all oil and grease before and after use. Also tighten all housing screws before and after use.

**Exercises (251):**

1. What is the purpose of the bench grinder?

2. How is the abrasive wheel checked for cracks?

3. Before and after you use the grinder what should you do?

4. What should you always wear when using a bench grinder?

## 4-3. Measuring Devices

Let us discuss a whole class of tools used for one purpose—measurement. These tools are covered in the 32 and 33 series technical orders. The tools range from ordinary measuring scales to precision meters that are used to analyze electronic circuit problems. Figure 4-32 is a conversion chart that will help in reading different scales.

### 252. State the two systems of graduations used on rules and their relative accuracy.

**Scales.** All rules (scales) are used to measure linear dimensions. They are read by a comparison of etched lines on the scale with an edge or a surface. Most scales' dimensions are read with the naked eye, but a magnifying glass can be used to read graduations on scales smaller than 1/64 inch.

**Steel Rules.** Steel rules (fig. 4-33) are available from a fraction of an inch in length up to 4 feet or more. There are several standard systems of graduations. In the English system, rules are graduated in 10ths, 20ths, 50ths, and 100ths; 12ths, and 48ths; 14ths and 28ths; and 16ths of an inch. In the metric system, rules are graduated in millimeters and one-half millimeters. Some steel rules have four scales, two on each side. There also are rules that have both inch scales and millimeter scales.

**Folding Rules.** Folding rules are obtainable in wood or metal, 2 to 6 feet long with 4 to 6 folds. These rules cannot be relied on for extremely accurate measurements, because a certain amount of play develops at the joints after they have been used.

**Exercises (252):**

1. What are the two systems of graduations used on rules?

2. What type of rule does not give you the most accurate measurements?

### 253. State the use of two types of squares.

**Squares.** The purpose of a square is to test work for squareness and trueness. It is also used as a guide when marking work for machining, sawing, planing, and chiseling. There are many types of squares; we will discuss two of the more common types here.

***Try squares.*** The try square is used for laying out work and determining whether edges and ends are true after work has been sawed, planed, or chiseled. Figure 4-33 illustrates several uses of the try square in which faces have to be at right angles to each other.

***Combination squares.*** The combination square is a versatile unit having many varied uses. Figure 4-34 shows the protractor head being used to check the angle of a lathe way. By setting the head at a definite angle, the variation can be measured. Square and combination sets are expensive, precision instruments and must be handled with care. Something as simple as a nicked or rusted edge can make the tool totally inaccurate. Store squares and combination sets in cases or in a well protected place.

The combination square is made up of the following components:

1. A slotted 12-inch stainless-steel rule that is graduated in eighths, sixteenths, thirty-seconds, and sixty-fourths of an inch. It can be used as a measuring scale by itself or with any one of the following components.

2. A center head. When attached to the rule, it bisects a 90 degree angle. It is used for determining the center of cylindrical work.

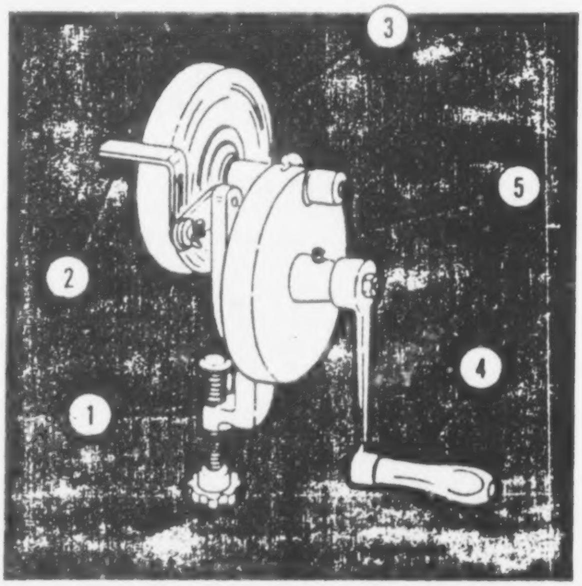


Figure 4-31 Bench grinder.

404-337

| FRACTION OF INCH | DECIMAL OF INCH | MILLIMETERS | FRACTION OF INCH | DECIMAL OF INCH | MILLIMETERS |
|---|---|---|---|---|---|
| 1/64 | 0.015625 | 0.3968 | 33/64 | 0.515625 | 13.0966 |
| 1/32 | 0.03125 | 0.7937 | 17/32 | 0.53125 | 13.4934 |
| 3/64 | 0.046875 | 1.1906 | 35/64 | 0.546875 | 13.8903 |
| 1/16 | 0.0625 | 1.5875 | 9/16 | 0.5625 | 14.2872 |
| 5/64 | 0.078125 | 1.9843 | 37/64 | 0.578125 | 14.6841 |
| 3/32 | 0.09375 | 2.3812 | 19/32 | 0.59375 | 15.0809 |
| 7/64 | 0.109375 | 2.7780 | 39/64 | 0.609375 | 15.4778 |
| 1/8 | 0.125 | 3.1749 | 5/8 | 0.625 | 15.8747 |
| 9/64 | 0.140625 | 3.5718 | 41/64 | 0.640625 | 16.2715 |
| 5/32 | 0.15625 | 3.9686 | 21/32 | 0.65625 | 16.6684 |
| 11/64 | 0.171875 | 4.3655 | 43/64 | 0.671875 | 17.0653 |
| 3/16 | 0.1875 | 4.7624 | 11/16 | 0.6875 | 17.4621 |
| 13/64 | 0.203125 | 5.1592 | 45/64 | 0.703125 | 17.8590 |
| 7/32 | 0.21875 | 5.5561 | 23/32 | 0.71875 | 18.2659 |
| 15/64 | 0.234375 | 5.9530 | 47/64 | 0.734375 | 18.6527 |
| 1/4 | 0.25 | 6.3498 | 3/4 | 0.75 | 19.0496 |
| 17/64 | 0.265625 | 6.7467 | 49/64 | 0.765625 | 19.4465 |
| 9/32 | 0.28125 | 7.1436 | 25/32 | 0.78125 | 19.8433 |
| 19/64 | 0.296875 | 7.5404 | 51/64 | 0.796875 | 20.2402 |
| 5/16 | 0.3125 | 7.9373 | 13/16 | 0.8125 | 20.6371 |
| 21/64 | 0.328125 | 8.3342 | 53/64 | 0.828125 | 21.0339 |
| 11/32 | 0.34375 | 8.7310 | 27/32 | 0.843750 | 21.4308 |
| 23/64 | 0.359375 | 9.1279 | 55/64 | 0.859375 | 21.8277 |
| 3/8 | 0.375 | 9.5248 | 7/8 | 0.875 | 22.2245 |
| 25/64 | 0.390625 | 9.9216 | 57/64 | 0.890625 | 22.6214 |
| 13/32 | 0.40625 | 10.3185 | 29/32 | 0.90625 | 23.0183 |
| 27/74 | 0.421875 | 10.7154 | 59/64 | 0.921875 | 23.4151 |
| 7/16 | 0.4375 | 11.1122 | 15/16 | 0.9375 | 23.8120 |
| 29/64 | 0.453125 | 11.5091 | 61/64 | 0.953125 | 24.2089 |
| 15/32 | 0.46875 | 11.9060 | 31/32 | 0.96875 | 24.6057 |
| 31/64 | 0.484375 | 12.3029 | 63/64 | 0.984375 | 25.0026 |
| 1/2 | 0.5 | 12.6997 | 1 | 1.0 | 25.3995 |

Figure 4-32. Conversion chart—fraction of an inch to decimals of an inch and millimeters.

3. A protractor, which has a level and a revolving turret that is graduated in degrees from 0 to 180 or 0 to 90 in either direction. It is used to lay out and measure angles within 1 degree.

4. A square head, which has a level, a scribe, and 45 degree and 90 degree sides. It is used to lay out 45 and 90 degree angles and to check level. It may also be used as a height or depth gauge.

**Exercises (253):**

1. What are the uses of the try square shown in figure 4-33?
2. What is the protractor head used for on the combination square?

### 254. Identify calipers and dividers with their use.

**Dividers and Calipers.** Dividers are used for measuring distances between two points, for transferring or comparing measurements directly from a rule, or scribing an arc, radius, or circle. Calipers are used for measuring diameters and distances, or for comparing dimensions or sizes with standards such as graduated rule.

***Dividers.*** The spring dividers (fig. 4-35) consist of two sharp points at the end of straight legs, held apart by a spring and adjusted by a screw. The spring dividers are available in sizes from 3 to 10 inches in length. The wing divider in figure 4-35 has a steel bar that separates the legs. The spring and wing type dividers are used to scribe arcs or circles on wood or metal.

***Calipers.*** Calipers (fig. 4-36) are made in many different designs and shapes. However, they are either outside calipers or inside calipers. They are used to measure inside or outside diameters. Figures 4-37 and 4-38 illustrate the use of calipers.

Hermaphrodite calipers (fig. 4-36) are a cross between dividers and inside calipers, each having one leg. These calipers are used for scribing parallel lines from an edge, or for locating the center of cylindrical work. Figure 4-39 shows some of the many uses.

There is one more type of caliper you might come in contact with. Figure 4-40 shows a vernier caliper. This caliper uses a vernier scale, and is used for large inside and outside measurements.

**Exercises (254):**

1. Match calipers or dividers in column A with the use in column B. Column B items may be used more than once.

*Column A*

_____ (1) Spring and wing dividers.
_____ (2) Hermaphrodite caliper.
_____ (3) Vernier caliper.

*Column B*

a. Scribing parallel lines.
b. Scribing arcs and circles on wood or metal.
c. For large inside or outside measurements.
d. Locating the center of cylindrical work.

### 255. Specify total measurement readings from the components of a micrometer.

**Micrometers.** Micrometers are among the most commonly used instruments for making measurements to an accuracy of 0.001 inch. They are used in one form or another in the maintenance and repair of precision photographic equipment. Common types of micrometers are the outside micrometer and the inside micrometer. Much of the special test equipment is equipped with micrometer adjustments.

Micrometers are made in various shapes and sizes, depending upon the purpose for which they are to be used. They all have a precision screw adjustment offering great measuring accuracy. Let's discuss some of the common micrometers.

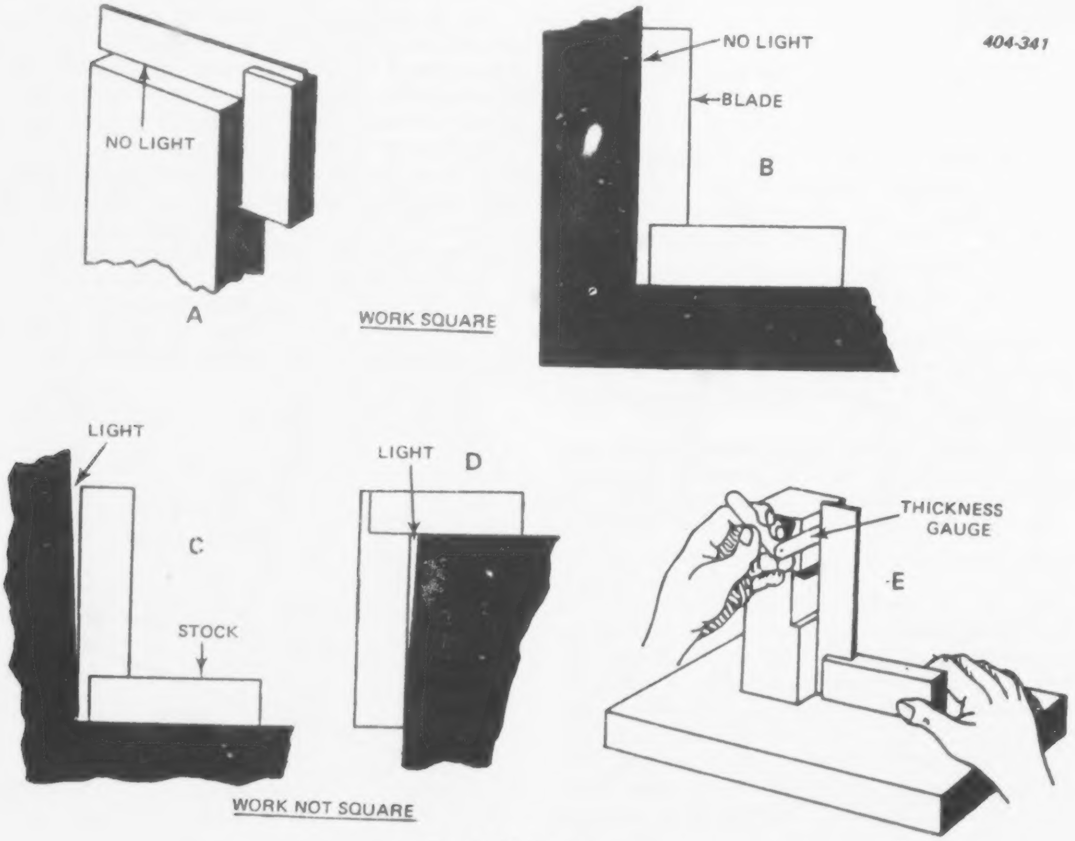


Figure 4-33. Using a try square.

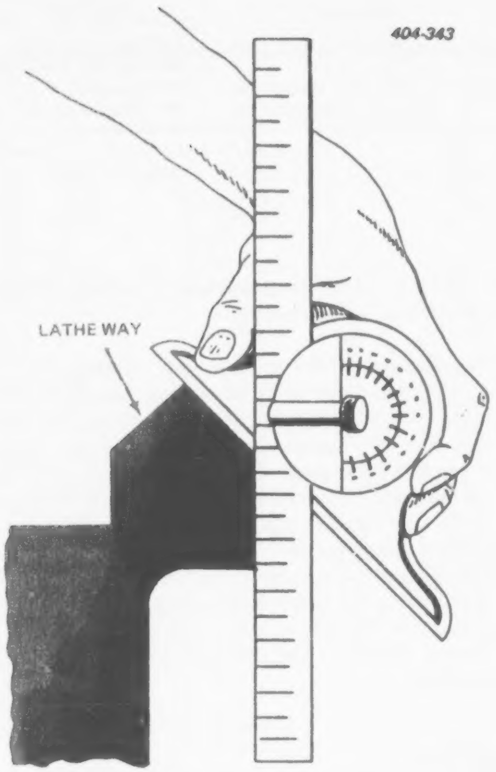


Figure 4–34. Using protractor head.

***Outside micrometer caliper.*** The micrometer caliper (fig. 4-41) is the most common type. It has a range of 0 to 1 inch and is graduated to read in thousandths of an inch or in units of the metric system, from 0 to 25 millimeters by hundredths of a millimeter.

The frame can be smaller to the extent that the range of the caliper is only 0 to 1/2 inch or 0 to 13 millimeters, or it can be larger so that the range is 23 to 24 inches. The head has a constant range of 0 to 1 inch. The shape of the frame may be varied to adapt it to the physical requirements of some types of work.

***Inside micrometer caliper.*** Inside micrometers are used to measure inside dimensions. The minimum dimension that can be checked is determined by the length of the unit with its shortest anvil in place and the screw set up to zero. It consists of an ordinary micrometer head, except that the outer end of the sleeve carries a contact point attached to a measuring rod. The average inside micrometer set has a range that extends from 2 to 10 inches. The various steps in covering this range are obtained by means of extension rods. The micrometer set may also contain a collar for splitting the inch step between two rods. The collar, which is 1/2 inch long, extends the rod another half inch so that the range of each step can be made to overlap the next. The range of the micrometer screw itself is very short when compared to its measuring range. The smallest models have a 1/4-inch screw, the average have a 1/2-inch screw, and the largest micrometers have only a 1-inch screw.

***Design.*** The micrometer makes use of the relation of the circular movement of a screw to its axial movement. The amount of axial movement of a screw per revolution depends on the thread, and is known as the lead. If a circular nut on a screw has its circumference divided into 25 equal spaces, and if the nut advances axially 1/40 inch for each revolution, then if it is turned one division, or 1/25 of a revolution, it will move axially 1/25 x 1/40, or 1/1000 of an inch. In the micrometer the nut is stationary and the screw moves forward axially a distance proportional to the amount it is turned. The screw on a micrometer has 40 threads to the inch, and the thimble has its circumference divided into 25 parts, so that division of the thimble represents an advancement of 1/1000 of an inch axially.

***Construction.*** The steel frame is U-shaped, with one end holding the stationary anvil. The stationary anvil is a hardened button either pressed or screwed into the frame.

The steel spindle is actually the unthreaded part of the screw. It is the spindle that advances or retracts to open or close the open side of the U-frame. The spindle bearing is a plain bearing and a part of the frame. The hollow barrel extends from this bearing. On the side of the barrel is the micrometer scale graduated in tenths of an inch, which are in turn divided into subdivisions of 0.025 inch. The end of the barrel supports the nut that engages the screw. This nut is slotted, and its outer surface has a taper thread and a nut that makes it possible to adjust the diameter of the slotted nut, within limits, to compensate for wear.

The thimble is a sleeve that fits over the barrel and is attached to the screw. The front edge of the thimble carries a scale broken down into 25 parts. This scale indicates parts of a revolution, whereas the scale on the barrel indicates the number of revolutions. The thimble is connected to the screw through a sleeve that permits it to be slipped in relation to the screw for the purpose of adjustment. The inner sleeve is sweated to the screw. The outer sleeve is clamped to the inner one by the thimble cap. Loosening the cap makes it possible to slip one in relation to the other.

On top of the thimble cap there may be a ratchet. The device consists of an overriding clutch held together by a spring in such a way that when the spindle is brought up against the work, the clutch will slip when correct

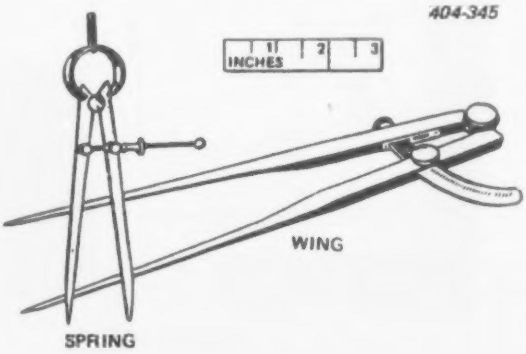


Figure 4–35. Dividers.

measuring pressure is reached. The purpose of the ratchet is to eliminate any difference in personal touch and so reduce the possibility of error due to a difference in measuring pressure. Not all micrometers have ratchets.

The clamp ring or locknut is located in the center of the spindle in any position to preserve a setting.

***Reading a standard micrometer.*** Reading a micrometer is only a matter of reading the micrometer scale or counting the revolutions of the thimble and adding to this any fraction of a revolution. The micrometer screw has 40 threads per inch. This means that one complete and exact revolution of the micrometer screw moves the spindle away from or towards the anvil exactly 0.025 inch. The lines on the barrel (fig. 4-42) conform to the pitch of the micrometer screw, each line indicating 0.025 inch and each fourth line being numbered 1, 2, 3, and so forth. The beveled edge of the thimble is graduated into 25 parts, each line indicating 0.001 inch, with 1/25 of the 0.025 inch covered by one complete and exact revolution of the thimble. Every fifth line on the thimble is numbered to read a measurement in thousandths of an inch. Read measurements shown in figure 4-42 as indicated in (1) through (4) below.

(1) Record the highest figure visible the barrel ............................... = 0.100 in.

(2) Number of lines visible between the No. 1 and the thimble edge ...................................... 3 = 0.075 in.

(3) The line on the thimble that coincides with or has passed the revolution or long line in the barrel ............ ............. 3 = 0.178 in.

(4) Total measurement reading ........ = 0.178 in.

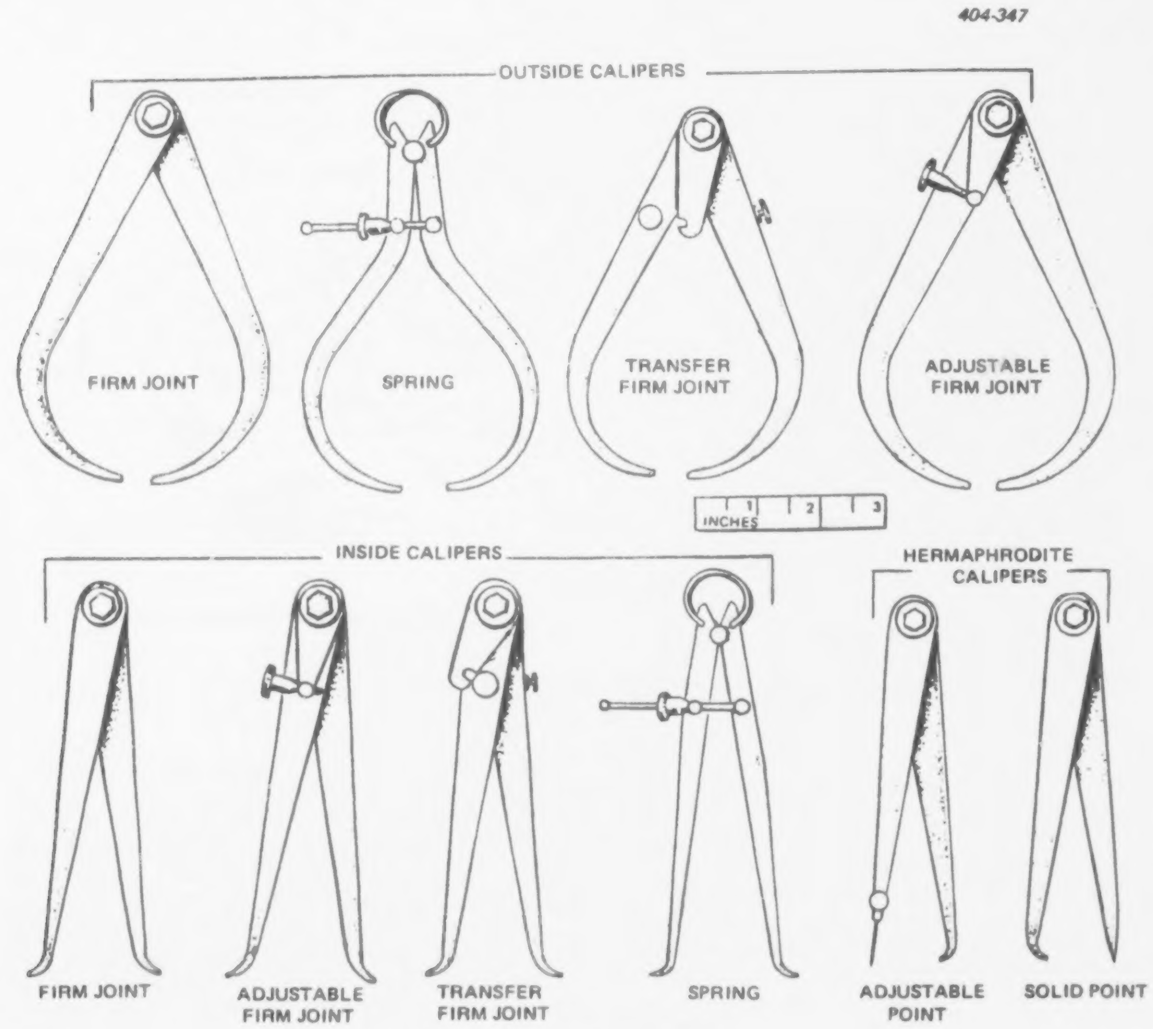
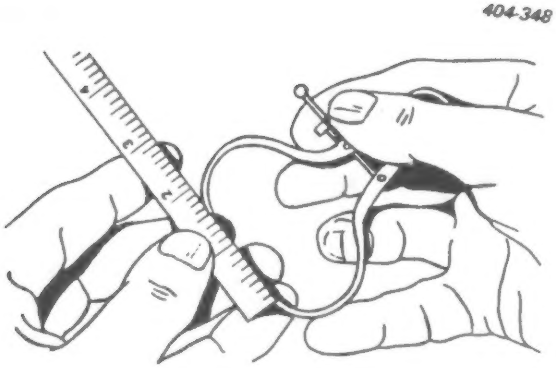
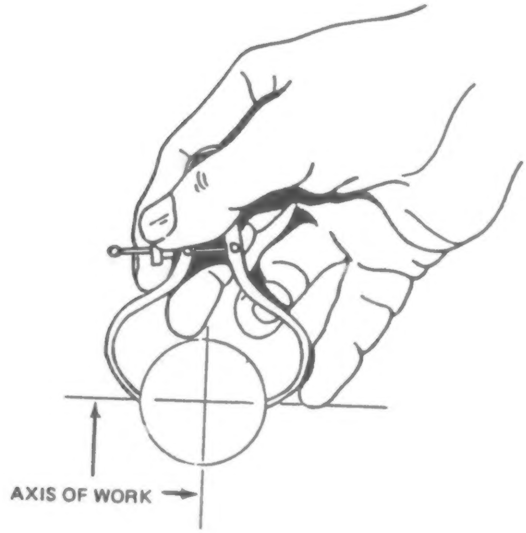


Figure 4-36. Calipers—noncalibrated.



A

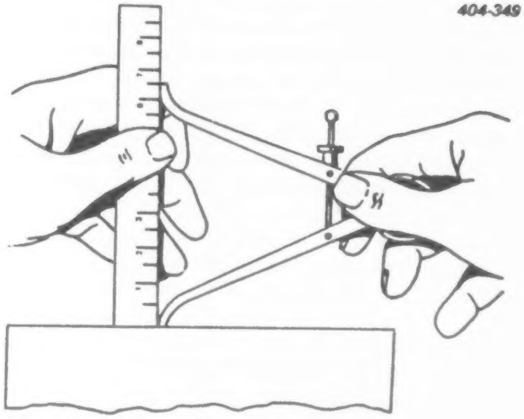
SETTING OUTSIDE CALIPERS ON RULE



B

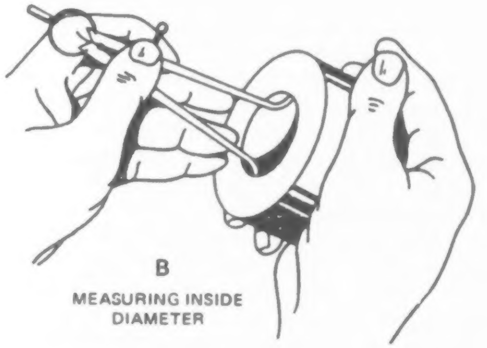
POSITIONING FOR CORRECT MEASUREMENT

Figure 4–37. Using outside calipers.



A

SETTING CALIPER



B

MEASURING INSIDE DIAMETER

Figure 4–38. Using inside calipers.

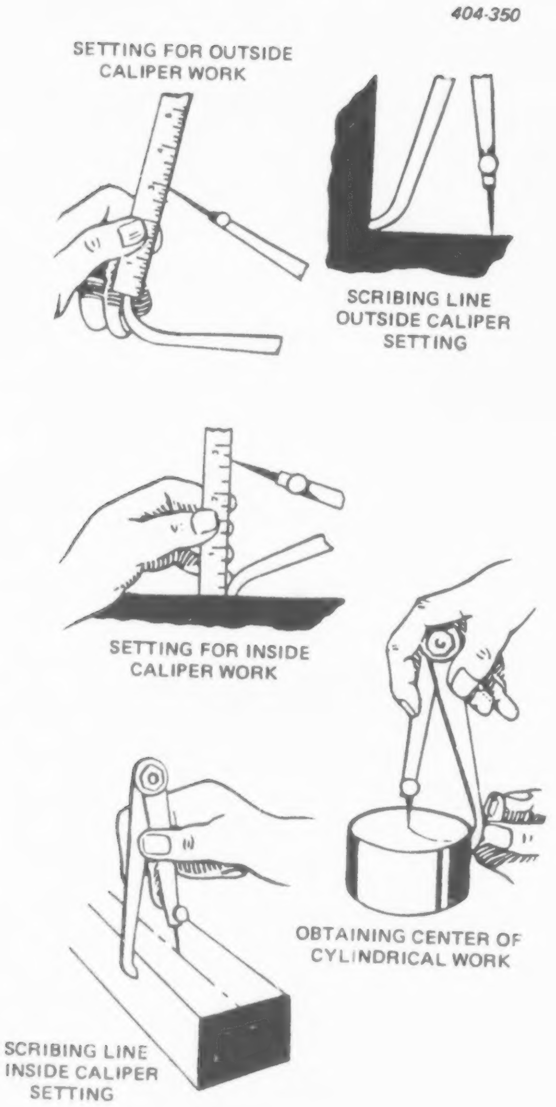

404-350
SETTING FOR OUTSIDE CALIPER WORK
SCRIBING LINE OUTSIDE CALIPER SETTING
SETTING FOR INSIDE CALIPER WORK
OBTAINING CENTER OF CYLINDRICAL WORK
SCRIBING LINE INSIDE CALIPER SETTING

Figure 4-39. Using hermaphrodite calipers.

***Applying the micrometer caliper to the work.*** Figure 4-43, part A, shows the proper way to hold a micrometer caliper in checking a small part. Hold the micrometer in the other hand so that the thimble rests between the thumb and the forefinger. The third finger is then in a position to hold the frame against the palm of the hand. Holding the micrometer in this manner supports the frame and makes it easy to guide the work over the anvil. The thumb and forefinger are in position to turn the thimble, either directly or through the ratchet, and bring the spindle over against the work.

On larger work, it is necessary to have the work stationary and positioned to permit access to the micrometer. The proper method of holding a micrometer when checking a part too large to be held in one hand is shown in figure 4-43, part B. The frame is held by one hand to position it and locate it square to the measured surface. The other hand operates the thimble either directly or through the ratchet. A large flat part should be checked in several places to determine the amount of variation.

To gauge a shaft as shown in C, figure 4-43, the frame is held by one hand while the thimble is operated by the other. In gauging a cylindrical part with a micrometer, it is necessary to "feel" the setting to be sure that the spindle is on the diameter and also to check the diameter in several places to determine the amount of out of roundness.

For measuring very large diameters, micrometer calipers are made in various sizes up to 168 inches.

**Exercises (255):**

1. Record the reading for the following information (fig. 4-42).

   a. Barrel reading = 4.

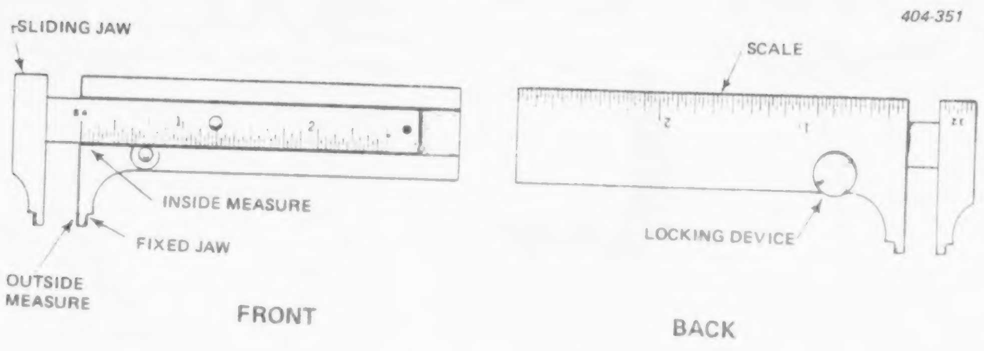
   b. Number of lines visible between the No. 4 and the thimble edge = 1.

   c. The long line on the barrel = 14.

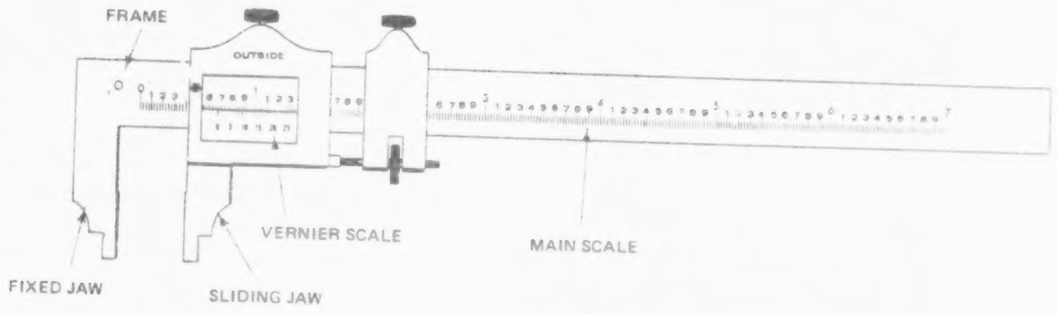
**256. State the purpose of different types of gauges.**

**Gauges.** Gauges are used for marking, measuring, and checking clearances. There are so many different types and designs that it would be impossible to discuss all of them in this section. We will discuss some gauges that are common to most photo maintenance.

There are four types of gauges that you will use—screw pitch gauge, twist drill gauge, wire gauge, and feeler gauge. However, any type of tool that is used as a measuring device is a gauge. You will find that some equipment has specially designed gauges that are used only for adjusting and calibrating the specific piece of equipment.



SLIDE CALIPER



VERNIER CALIPER

Figure 4-40. Calipers—calibrated.

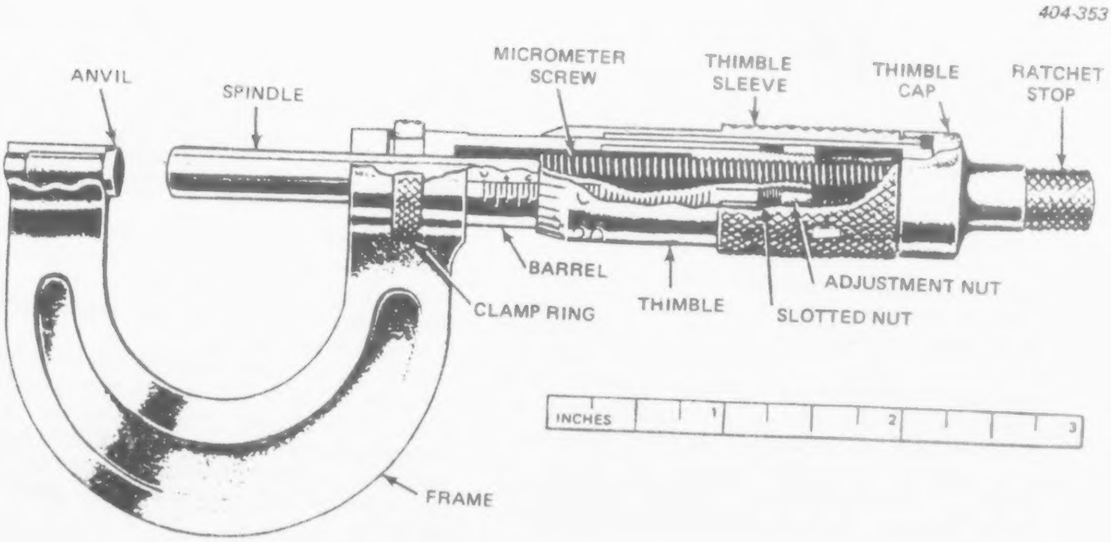


Figure 4-41. Micrometer caliper, cutaway view.

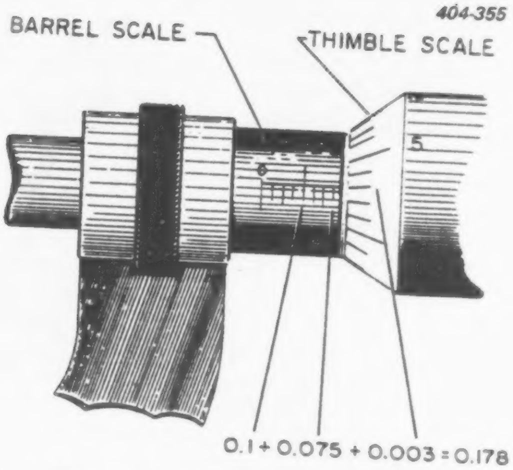


Figure 4–42. Reading a standard micrometer scale.

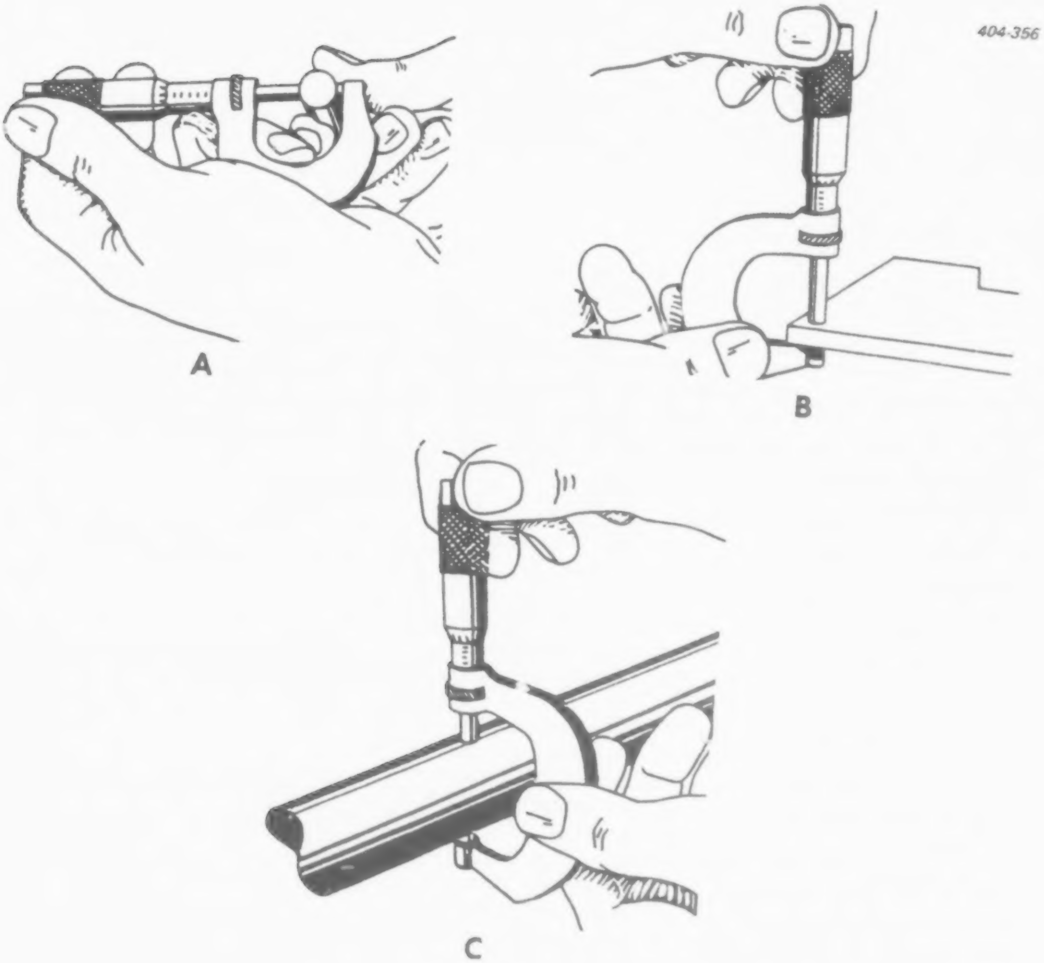


Figure 4–43. Using an outside micrometer.

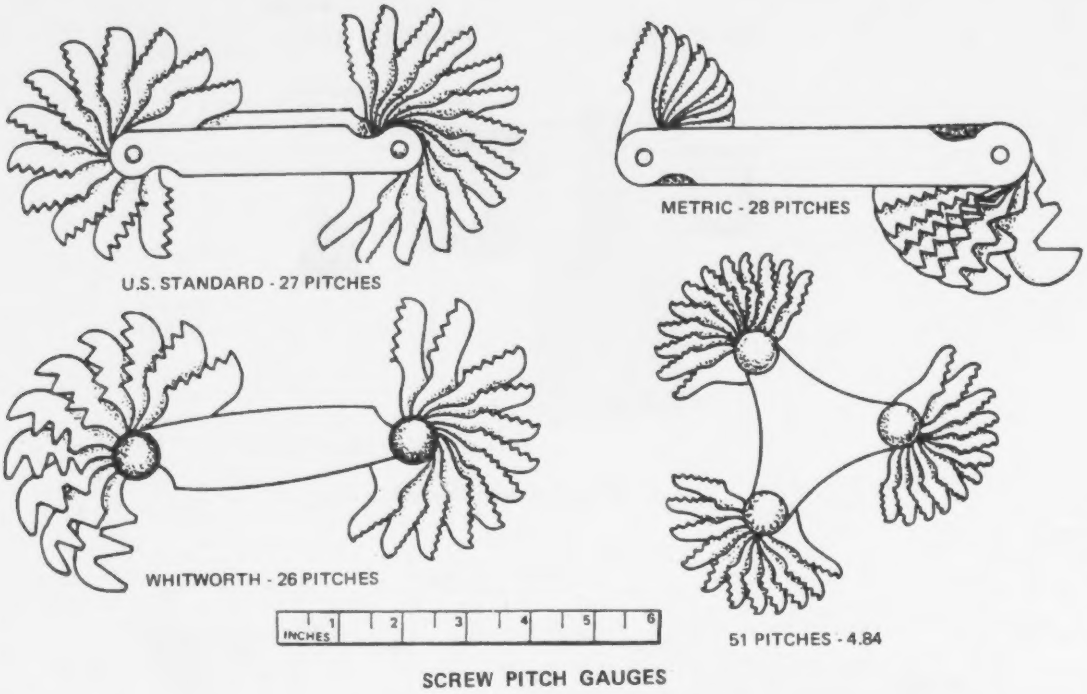


Figure 4-44. Center and screw pitch thread gauges.

***Screw pitch gauge.*** The screw pitch gauge (fig. 4-44) consists of a holder that contains a number of blades with teeth corresponding to the various screw threads. Each blade is marked to indicate the number of threads per inch. Figure 4-44 shows screw pitch gauges used for checking the pitch of U.S. standard, metric, national form, V-form, and Whitworth cut threads.

If the pitch of a thread is not known, it can be determined by comparing it with the standards on the various screw pitch gauges. Refer to figure 4-45. Place a blade of a gauge over the threads and check to see if it meshes. If not, use a different blade until one is found that meshes with the threads. The blades are made pointed so that they can be inserted into small nuts to check inside threads as well as outside threads.

***Twist drill and drill rod gauge.*** The twist drill and drill rod gauge (fig. 4-46) has a series of holes with size and decimal equivalents stamped adjacent to each hole. One gauge measures drill sizes 1 to 60; the other gauge measures drill sizes 1/16 to 1/2 inch by 1/64-inch intervals.

***Wire gauges.*** The wire gauge, figure 4-46, is circular with cutouts in the outer perimeter. Each cutout gauges a different size of wire, from 0 to 36 of the English Standard Wire Gauge. A separate gauge is used for American standard wire and another for U.S. standard sheet and plate iron and steel.

***Thickness (feeler) gauges.*** Thickness gauges are made in many shapes and sizes. Usually 2 to 26 blades are grouped in one tool and graduated in thousandths of an inch. They are used for checking and measuring small openings, such as contact points and narrow slots.

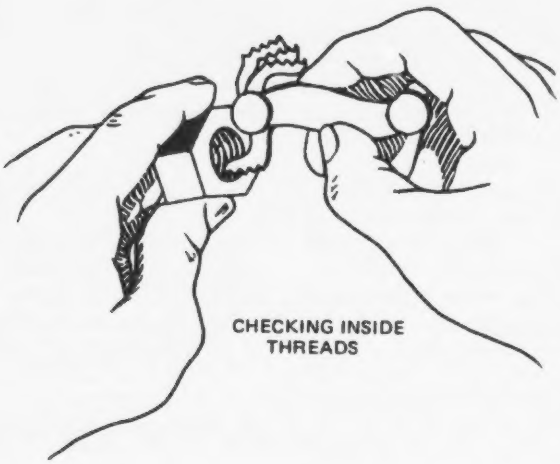
**Exercises (256):**

1. What type of gauge would you use to check the clearance of a mating surface?

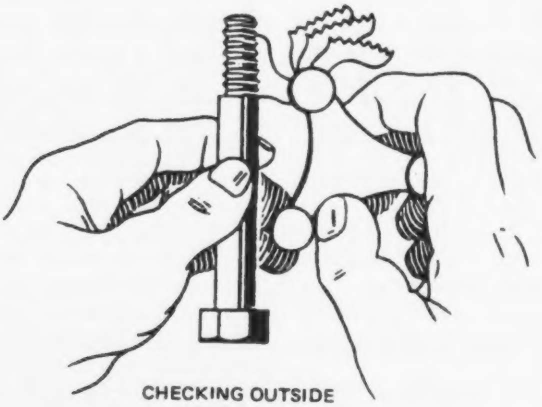
2. What gauge would you use to determine the number of threads on a bolt?

3. What gauge would you use to measure the size of a drill?

4. What type of gauge measures wire sizes?

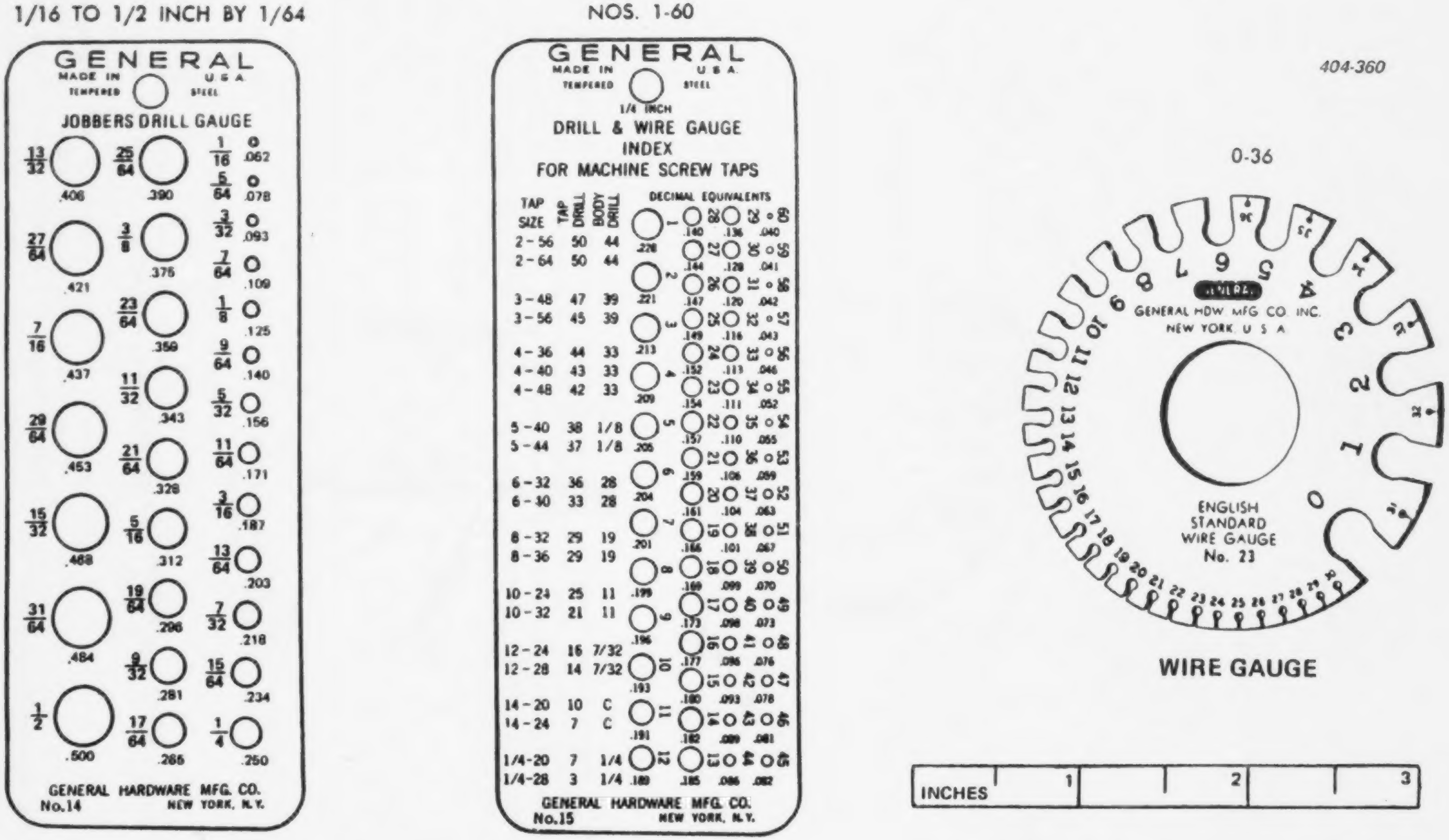


CHECKING INSIDE THREADS



CHECKING OUTSIDE THREADS

Figure 4-45. Using screw pitch gauges.



| TAP SIZE | TAP DRILL | BODY DRILL |
|---|---|---|
| 2 - 56 | 50 | 44 |
| 2 - 64 | 50 | 44 |
| 3 - 48 | 47 | 39 |
| 3 - 56 | 45 | 39 |
| 4 - 36 | 44 | 33 |
| 4 - 40 | 43 | 33 |
| 4 - 48 | 42 | 33 |
| 5 - 40 | 38 | 1/8 |
| 5 - 44 | 37 | 1/8 |
| 6 - 32 | 36 | 28 |
| 6 - 40 | 33 | 28 |
| 8 - 32 | 29 | 19 |
| 8 - 36 | 29 | 19 |
| 10 - 24 | 25 | 11 |
| 10 - 32 | 21 | 11 |
| 12 - 24 | 16 | 7/32 |
| 12 - 28 | 14 | 7/32 |
| 14 - 20 | 10 | C |
| 14 - 24 | 7 | C |
| 1/4-20 | 7 | 1/4 |
| 1/4-28 | 3 | 1/4 |

TWIST DRILL AND DRILL ROD GAUGES

WIRE GAUGE

Figure 4–46. Drill and wire gauges.

CHAPTER 5

# Soldering

ONE OF THE MOST important tasks performed on electronic assemblies is soldering. This chapter discusses the basic tools and techniques for soldering wires, terminals, printed circuits boards, and integrated circuits. It also covers the precautions to take when performing these tasks.

## 5-1. Soldering precautions and tools

It is very important that you follow the proper procedure and safety precautions during soldering. The soldering process requires the use of tools at high temperature which could be hazardous to one's health. Following the correct procedure and using proper tools is an important factor in providing a high quality finished product.

### 257. State the purpose and process of soldering and cite related precautions.

**Soldering.** Soldering is the process of joining two (or more) metals together by the application of heat and a low melting point alloy that flows between and around the metals being joined and, upon cooling, solidifies and bonds the metal together. In its molten state, solder chemically dissolves part of the metal surfaces to be joined. However, most metals exposed to the atmosphere acquire a thin film of tarnish or oxide; the longer the exposure the thicker the film will become. This film is present even though it is not visible, and solder alone cannot dissolve it. A soldering flux with a melting point lower than the solder must be used to "wet" the metal and penetrate and remove the film. The flux melts first, removing the tarnish or metallic oxide, and also prevents further oxide from forming while the metal is being heated to soldering temperature. The solder then melts, floating the lighter flux and the impurities suspended in it to the outer surface and edges of the molten fillet. The solder cools and forms an alloy with the metal. Most of the flux is burned away during the soldering process; any residue is removed by appropriate cleaning methods.

Soldered connections are used in electronic equipment to form a continuous and permanent metallic connection having a constant electrical value. The importance of establishing and maintaining a high standard of workmanship for soldering operations cannot be overemphasized.

**Safety Precautions When Soldering.** Let's look at some safety precautions pertinent to soldering. Soldering is a safe process if you recognize the hazards associated with it and observe precautions. The risk of painful and dangerous burns is always present during soldering and desoldering operations. You can receive burns from soldering irons or from handling soldered connections or parts that have not cooled. When soldering on electronic equipment, exercise the following cautions:

*a.* Protect eyes and skin with proper clothing and other protective devices—soldering fluxes frequently spatter when they are heated.

*b.* Never rest a hot soldering iron on a wood bench or chair; instead, use an appropriate soldering iron holder.

*c.* Never flip excess solder from the tip of the soldering iron, wick, or wire lead. Bits of hot solder can cause serious skin and eye burns. Use a clean, damp sponge or cloth for removing excess hot solder.

*d.* Never wear rings or watches while soldering. A small solder spatter caught under a ring or wristwatch can cause a severe burn.

*e.* Always disconnect electronic systems equipment from the power source before soldering. Serious burns, even death, can result from contact with energized high-voltage or high-current circuits.

*f.* Always ground soldering irons or guns to eliminate electric shock due to defective equipment.

*g.* Always provide adequate ventilation. Fumes from fluxes and cleaning solvents may contain toxic gases.

*h.* Never allow fluxes or cleaning solvents to remain on the skin unnecessarily. Materials in these products can irritate skin. Wash with water.

*i.* Immediately after soldering, wash your hands thoroughly before eating or smoking. Most fluxes contain materials that are health hazards if ingested.

**Exercises (257):**

1. What is the purpose of soldering?

2. What is soldering?

3. Cite at least six precautions you should observe when soldering.

## 258. Specify what must be done to prepare for soldering.

**Soldering Iron.** A soldering iron (fig. 5-1) is the most common tool used for heating metals to be joined with soft solder. The tip of a soldering iron is usually made of copper, a good conductor of heat. Tips might be in any shape or size, depending upon the nature and size of the material being soldered. In figure 5-1,A you can see how the ends of the tips may be shaped. Figure 5-1,B shows two different types of power plugs other than the standard two-prong shown in figure 5-1,A. The curved shape tip in figure 5-1,B, is for soldering in areas that cannot be easily reached with the straight tips. Special soldering irons are developed for soldering multiple connections, such as transistors and package-mounted components on printed circuit boards. Some soldering irons are equipped with "sniffers"—devices designed to remove melted solder and facilitate multiple-terminal component removal.

**Tinning.** Properly prepare a soldering iron before using it. The procedure is called tinning the iron. It involves coating the tip with a thin layer of solder to aid the transfer of heat from the soldering iron to the metal being soldered. Heat passes through the liquid solder more easily than it passes through air. Tinning also aids in picking up excess solder and in applying solder to the desired spot. To tin the tip of the soldering iron, follow these steps in the order given:

*a*. Clean, shape, and smooth the cold tip.

*b*. Heat the soldering iron.

*c*. Rub the tip on a surface where both solder and flux can be applied simultaneously while the tip heats.

*d*. Continue the procedure until the iron gets hot enough to melt the solder and coats the tip.

*e*. Wipe excess solder from the tip with a clean damp sponge or cloth.

Soldering is simple if sufficient heat is available and you use the following procedures:

*a*. Clean the surface to be soldered, using emery cloth, sandpaper, steel wool, or a file.

*b*. Apply a small amount of flux to the two surfaces to be soldered.

*c*. Place the two pieces in their proper positions.

*d*. Apply the heated soldering iron under the surfaces being soldered, when possible. Remember, heat rises from the iron.

*e*. Apply the solder.

*f*. Hold the heat on the article only until the solder flows freely.

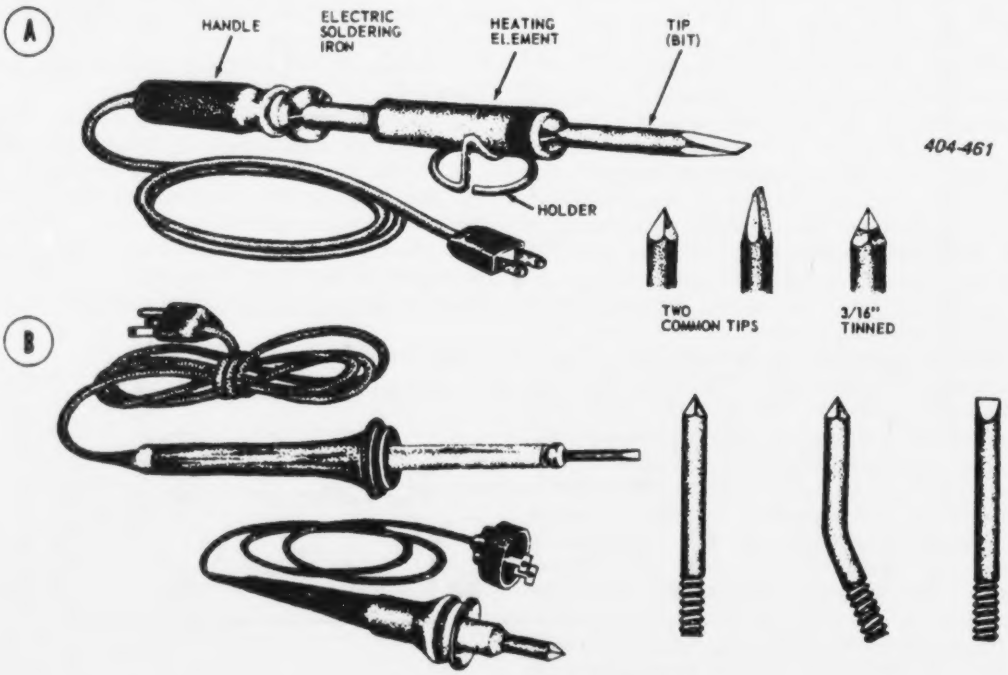


Figure 5-1. Soldering irons and tips.

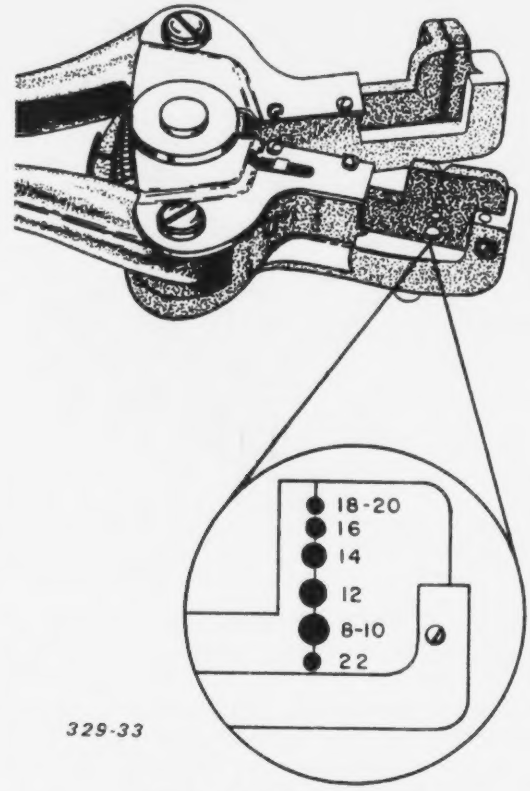


Figure 5–2. Mechanical wire strippers.

*g*. Remove the heat and allow the article to cool. Do not change the positions of the two surfaces during the cooling process.

*h*. Use a heat sink (something to absorb unwanted heat) to protect items that are subject to heat damage.

Sometimes it is convenient to sweat-solder two pieces together. Tin the two surfaces separately. Put them in the desired position. Apply sufficient heat to cause the solder to flow. Allow the joint to cool without being disturbed.

Always keep the soldering iron properly shaped, well-tinned, and free from corrosion and pitting. If irons have removable tips, remove the tips after each use. Clean the iron, the tip receptacle, and the tip thoroughly before you reassemble and store the iron.

**Exercises (258):**

1. Why is the tip of a soldering iron usually made of copper?

2. What procedure is necessary before using the soldering iron?

3. List the five steps to follow when tinning the tip of the soldering iron.

4. What must you use to protect items that are subject to heat damage?

### 259. Cite uses of tools for soldering and desoldering.

**Mechanical Wire Stripper.** The mechanical wire stripper (fig. 5-2) is designed to strip the insulation from an electrical wire in one operation. It has two sets of jaws. One set holds the wire while the other cuts and pulls off the insulation. Use the tool by following these steps:

*a*. Determine the size of wire to be stripped.

*b*. Place the wire between the proper set of cutting teeth. The length of wire to be stripped extends beyond the cutting jaw.

*c*. Squeeze the handles until the cutting teeth come together.

*d*. Continue to squeeze. The holding jaw closes on the part of the wire that is not to be stripped. The cutting teeth cut through the insulation and then move outward, pushing the cut insulation toward the end of the wire.

*e*. Release the handles. If the cut insulation does not fall off the wire, simply pull it off.

Do not strip wire with a set of cutting teeth that are too small. This causes the teeth to cut into the wire, dulls the teeth, weakens the wire, and eventually throws the cutting jaws out of alignment. Protect the cutting teeth when the tool is in use or in storage. Oil the pivot points regularly.

**Thermal Wire Stripper.** This type of wire stripper (fig. 5-3) is designed to remove the insulation from an electrical wire by heated steel-alloy blades. It is self-contained, very compact, and it uses no external transformers or power supplies. Its heated steel-alloy blades are mounted on electrodes protruding from the front of the wire stripper. The upper blade and electrode assembly is mounted on a movable arm, which is operated by the thumb to apply pressure to close the jaws, and contains a small red button that is depressed to heat the blades.

As shipped from the factory, the blades are notched to receive AWG 24 or larger wire. To meet stripping requirements, the notch should be slightly larger than the diameter of the wire to be stripped. For wire smaller than AWG 32, unnotched blades should be used. Notched blades for any size wire may be obtained from Supply.

After considerable use, the stripper blades become encrusted with residue from the wire coverings. Sometimes this residue can be burned off by the application of full heat to the blades for a minute. If heat does not burn off the residue, use a soft wire brush to clean the blades. When installing new blades, carefully check the alignment of the

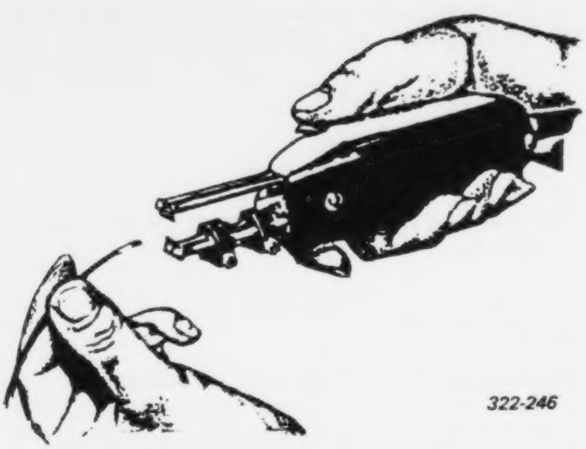


Figure 5–3. Thermal wire strippers.

notches and make certain the retaining screws are tightened.

There is one caution you should observe when using the thermal wire stripper. Teflon, PVC, and silicone-rubber insulations should be stripped in a well-ventilated area, because in the process a small amount of toxic gas may be emitted.

Other tools and materials used in soldering and desoldering include the following:

*a.* Wire-bending tools are used to connect wires to terminals. Wire benders must have smooth-bending surfaces that bend wires and leads without nicking or otherwise damaging the lead or part. Needlenose pliers may be used for bending wires and leads if the jaw tips are encased in covers of copper tubing as shown in figure 5-4.

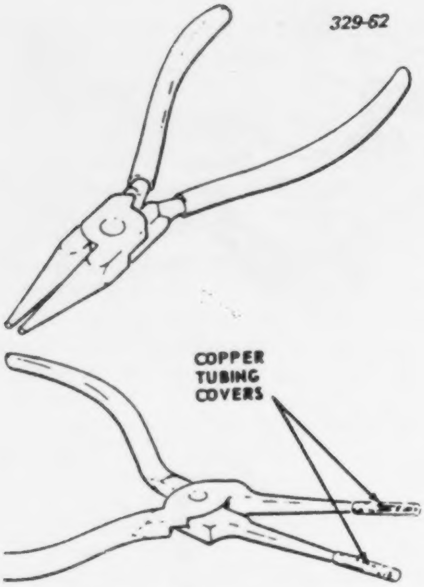


Figure 5–4. Wire bending tools.

*b.* Use only approved solvents for removing excess flux from soldered connections and for general cleaning of electronic parts.

*c.* Use flexible insulation tubing to cover wiring, part leads, and soldered terminal connections.

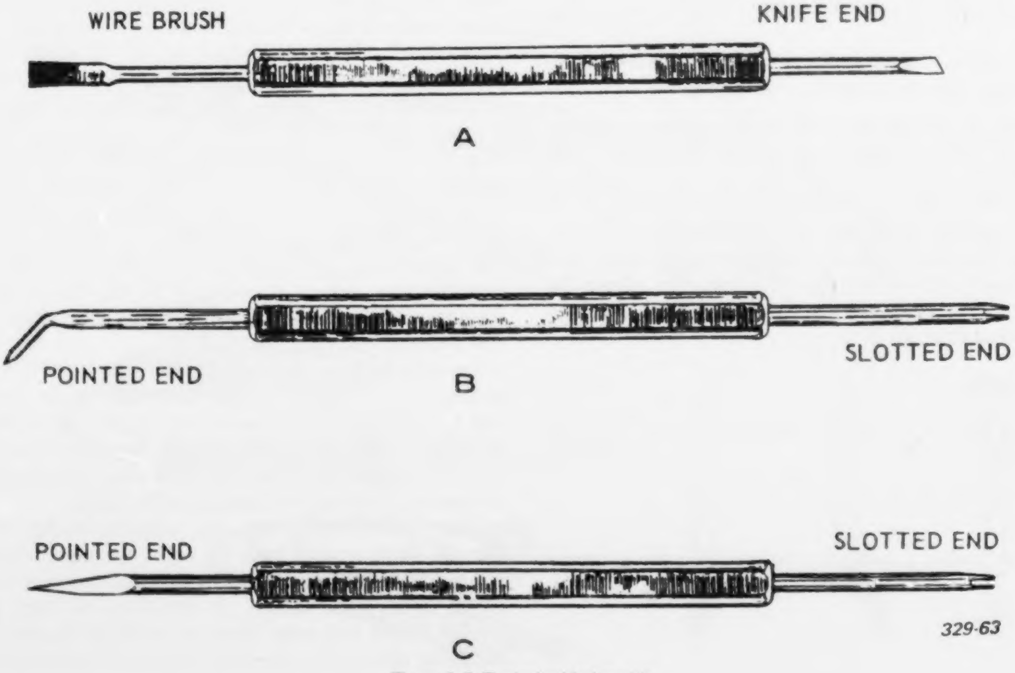


Figure 5–5. Typical soldering aids.

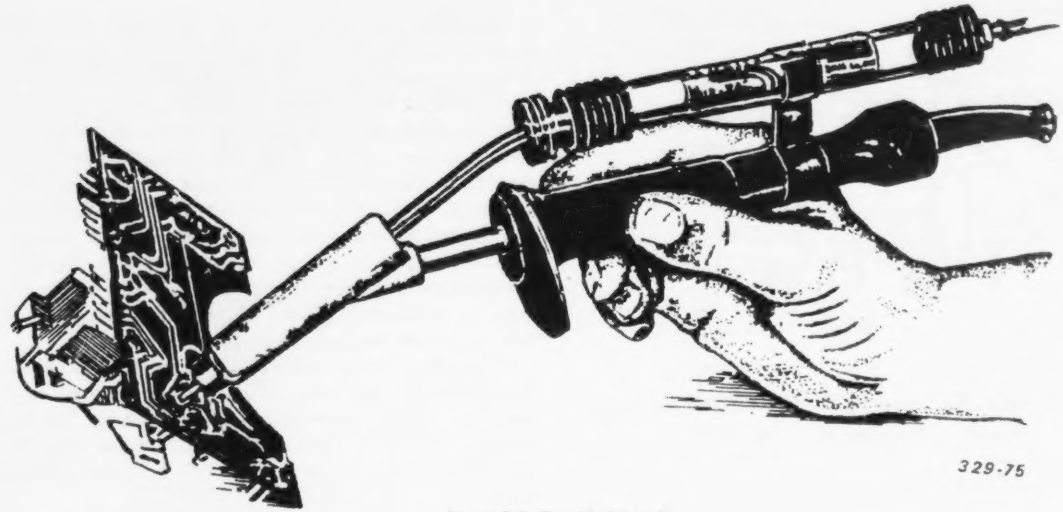


Figure 5-6. Desoldering tools.

*d.* Soldering aids, such as those shown in figure 5-5, are useful in the desoldering of soldered connections. Use slotted ends to lift the ends of wires and part leads from terminals. Use the pointed ends to remove solder from terminal holes and slots. Use the wire brush and knife end to remove molten solder.

*e.* You can also desolder with a tool such as that shown in figure 5-6. To use this tool, depress the vacuum bulb with the index finger or thumb, and place the heated tip against the soldered connection. When the solder on the connection melts, quickly release the vacuum bulb. This draws molten solder into the tube of the desoldering tip. Quickly place the desoldering tip over a metal waste container and depress the bulb to eject the molten solder.

**Exercises (259):**

1. What is one caution that you should observe when using the thermal wire stripper?

2. For what purpose are mechanical wire strippers designed?

3. What is the result of using wire strippers with a set of cutting teeth that are too small?

4. How can needlenose pliers be used to bend wires?

5. Which of the soldering aids shown in figure 5-5 are used to remove molten solder?

## 5-2. Soldering Wires

Almost all electrical circuits contain some type of wire connections. Properly soldered wire connections could eliminate a lot of malfunctions and unnecessary troubleshooting time.

**260. Specify the process used to solder wires.**

**Preparing the Wire.** Preparing the wires for soldering is as important as cleaning and tinning the soldering iron. Cut wires to the required length and then strip, clean, and tin them before attachment. Use the stranded type of hookup wire unless solid hookup wire is required by design. Be sure the unsupported, solid hookup wire does not exceed 5/8 inch between soldered connections. If wires exceed this length, they must be rigidly secured (or supported) at 5/8 inch intervals.

Always use an approved stripper to remove insulation from wires. The length of stripped wire is determined by the type of terminal, whether maximum or minimum wrap is used, and by the required amount of insulation clearance. Insulation clearance is the length of exposed bare wire between the insulation and the terminal after the connection has been completed. This clearance is measured from the outside edge of the terminal connection to the insulation on the wire, as shown in figure 5-7. The insulation clearance is determined as follows:

*a.* Wires having an outside diameter (including insulation) of 1/32 inch or less are provided with a minimum insulation clearance equal to the outside diameter and a maximum insulation clearance of 1/32 inch.

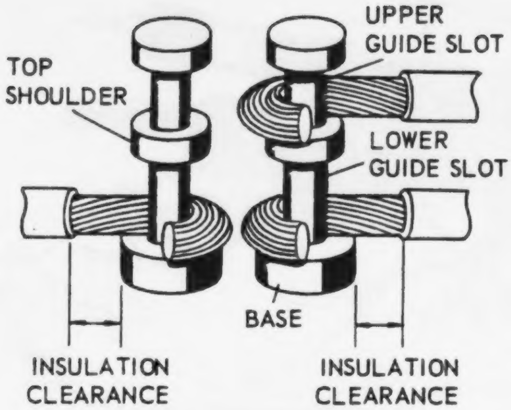


Figure 5-7. Turret terminal connections.

*b.* Wires having an outside diameter (including insulation) more than 1/32 inch are provided with a minimum insulation clearance of 1/32 inch and a maximum insulation clearance of the outside diameter, plus 1/32 inch.

After stripping the insulation, examine the wire for insulation damage. Never use wires that have cut, split, or burned insulation. Slight discoloration from thermal stripping is acceptable. Always ensure that the wire is not scratched, nicked, cut, scraped, or otherwise damaged. Damaged wires degrade connection reliability and are never used. When removing insulation with a mechanical wire stripper, ensure that the correct size of stripping hole is being used for the wire size. After stripping the insulation, twist the stranded wire in the direction that maintains the original form and prevents separation of the individual strands.

Shielded wires, or cables, are used to reduce the possibility of introducing noise into circuits having low-level signals. A typical shielded wire consists of an insulated wire surrounded by a tinned, braided shielding. Prepare for soldering a connection as you would any other wire lead. The pigtail method of preparing a shielded wire or cable for a soldered connection is shown in figure 5-8. To make a pigtail:

*a.* Determine and mark the point where shielding is to terminate.

*b.* Push the shielding back to form a bubble at the termination point (fig. 5-8,A).

*c.* Insert the pointed end of a soldering aid (fig. 5-8,A) into the shielding braid at the termination point and carefully work an open circular area in the shield.

*d.* Bend the wire and insert the pointed end of a soldering aid between the shielding and the insulated wire (fig. 5-8,B). Next, pull the insulated wire through the open, circular area in the shielding.

*e.* Pull the empty part of the shielding taut and tin the end to prevent fraying (fig. 5-8,C).

*f.* Strip the insulation from the center wire and prepare it for soldering to the terminal connection. Exercise extreme care while forming the pigtail to avoid damaging the shielding or the insulated wire.

**Soldering the Wire.** During soldering and cooling, support the wire lead, or part lead, so there is no movement. Apply the working surface of the heated soldering tip to the connection so that it transfers optimum heat to the surfaces being soldered. When the surfaces of the connection are hot enough to melt solder, apply the proper amount of solder directly to the connection. Maintain contact between the soldering tip and the connection until all the flux boils out and the solder completely fuses in a smooth, continuous blend with the wire and the terminal surfaces. Do not melt solder on the soldering tip and then allow the solder to flow onto the connection. Do not overheat the connection, even though you are using the thermal shunt.

A properly completed solder connection is shown in figure 5-9,A. The wire contacts the terminal, and its contour is visible under a thin solder coating. The solder, forming a concave fillet on each side of the wire, blends into the terminal surface in a smooth, continuous feathered edge.

When the wire is insufficiently cleaned or heated, an incorrect solder connection results (fig. 5-9,B). In this illustration the solder does not cover the wire. Instead, it terminates in small convex fillets on each side of the wire. In figure 5-9,C the solder fillet does not spread into a smooth blend with the terminal surface on each side of the wire.

**Exercises (260):**

1. What should you use to remove insulation from wires?

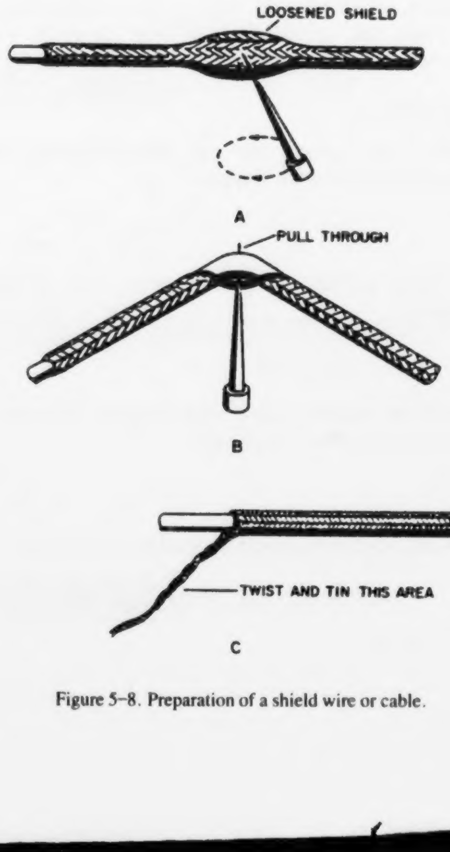


Figure 5-8. Preparation of a shield wire or cable.

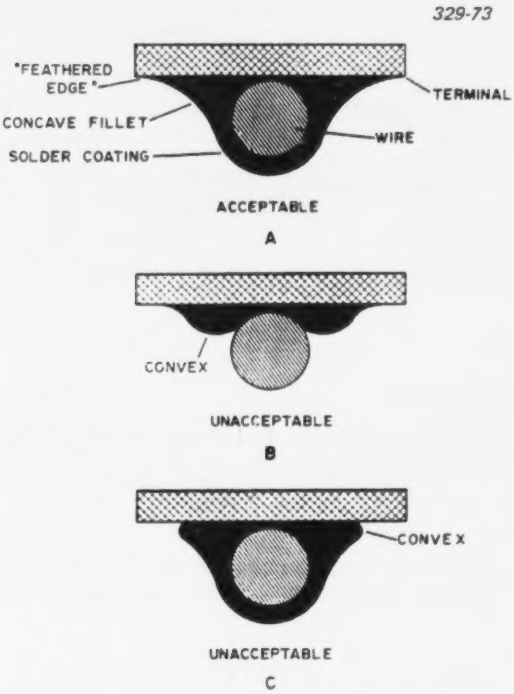


Figure 5-9. Cross section of acceptable and unacceptable solder connections.

2. After stripping insulation from the wire, how should you twist the strands of wire together?

3. Why must extreme care be taken in forming a pigtail with shielded wire?

4. What must be done during the soldering and cooling of a wire lead?

5. Describe a properly soldered connection.

### 261. Cite specifications for soldering terminals.

**Terminal Connections.** Before soldering part leads or wire leads to terminal connections, clean the terminals. You can do this with a pencil-style typewriter eraser. Clean the terminals until the tinned surfaces are bright and shiny and then wash them with an approved solvent immediately before soldering.

When soldering to a turret terminal or binding post, wrap the wire or lead around the terminal a minimum of 180° and maximum of 360°. The 180° wrap is shown in figure 5-7. The wire rests tightly against the base and enters the terminal in a straight line. Wire that does not enter the terminal in a straight line pulls against the solder rather than the terminal.

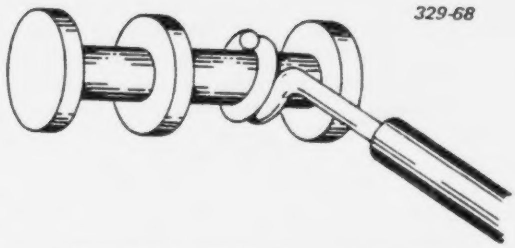


Figure 5-10. Incorrect turret terminal connections.

In wrapping wire or leads, do not make an incorrect mechanical connection. An example of an incorrect mechanical connection is one with space between the wire and terminal base. When insulation clearance is excessive, the signal can short out. Wrapping the wire around the terminal 1½ times, as shown in figure 5-10, makes desoldering very difficult.

The flat, perforated terminal may also be used in sensors. Some typical parts using flat, perforated terminals are shown in figure 5-11. Attach a wire to this type of terminal, using a minimum of one full wrap or a maximum of 1½ wraps. Two correct wraps are shown in figure 5-12 and an incorrect wrap is shown in figure 5-13. In figure 5-13, the wire pulls against the wrap rather than against the terminal and the insulation clearance is insufficient. If space is insufficient to make the 1½ wraps, crimp the wire after feeding it through the terminal hole, as shown in figure 5-14.

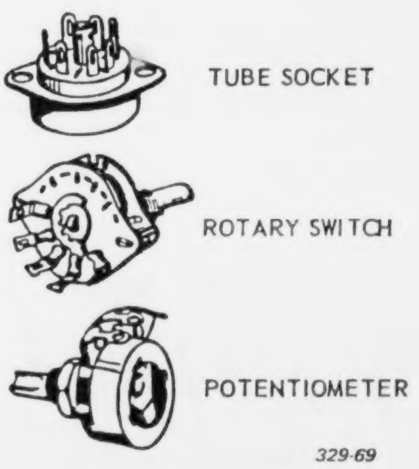


Figure 5-11. Typical parts using flat perforated terminals.

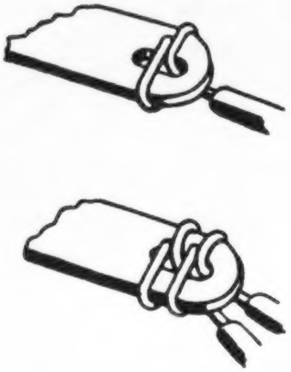


Figure 5–12. Correct wrap for flat perforated terminals.

The soldering operations for hollow cylindrical terminals (or solder cups) and connector pins are somewhat different from the soldering operations for turret terminals. Heat the solder cup terminal, or connector pin, and melt a small amount of solder inside the terminal before inserting the tinned wire. When inserting the tinned wire, keep the soldering tip in contact with the terminal until all flux is boiled out and the solder fuses smoothly onto the conductor and terminal surfaces. Make certain that the solder cup terminals contain enough solder to completely fill the cup when the solder is melted and the tinned wire is fully inserted into the cup. The wire replacement into a solder cup terminal is shown in figure 5-15. Observe both the placement and the insulation clearance.

Each soldered connection should be cleaned and inspected after the solder cools. Use a medium-stiff brush, dipped in a cleaning solvent, to remove flux and impurities from completed soldered connections. Ensure that the solder connections have a shiny, bright appearance, with no pits or holes, and that a good concave fillet exists between the wire and the terminal. Above all, ensure that no excess solder exists. Remember, the contour of the wire should be visible and the end of the wire should not extend beyond the terminal dimensions.

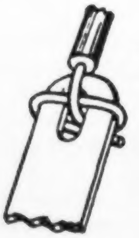


Figure 5–13. Incorect wrap for flat perforated terminals.

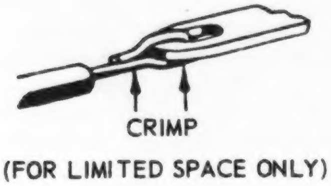


Figure 5–14. Limited space wrap for flat perforated terminals.

**Exercises (261):**

1. What can you use to clean the terminals with before soldering?

2. What is the minimum and maximum amount of wrap the wire should be when soldering to a turret terminal?

3. What is the minimum and maximum amount of wrap the wire should be when soldering to a flat, perforated terminal?

## 5-3. Soldering Printed Circuit Boards

The soldering of components on printed circuit boards could be very complicated. Because of the limited space between components, proper techniques, procedures, and the use of proper tools are critical in the removal and replacement of components on printed circuit boards.

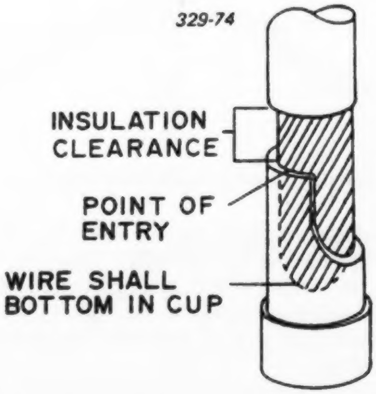


Figure 5–15. Wire placement in a solder cup.

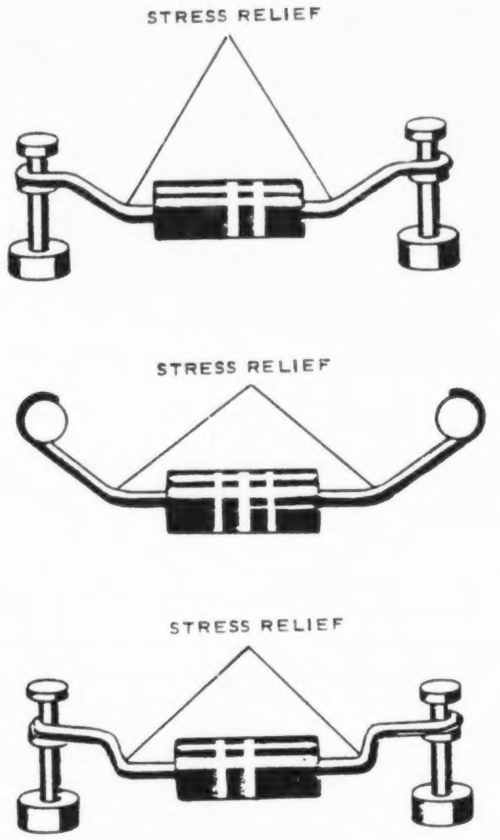


Figure 5–16. Typical stress relief bend in part leads.

### 262. Cite the process used for soldering printed circuit (PC) board components.

**Removing and Replacing PC Board Components.** The parts on printed circuit boards are grouped in two general classifications: lead-mounted and flush-mounted parts. Typical examples of lead-mounted parts are resistors, coils, capacitors, and many types of transistors. Flush-mounted parts have both leads protruding from the same end, since they are specifically designed for printed circuit boards. Examples of flush-mounted parts are miniature electrolytic capacitors and small, integrated, encapsulated arrangements of resistors, coils, and capacitors.

Removing a part from a printed circuit board is often much more difficult than replacing that part. This is especially true of flush-mounted parts with multiple connections. Because of the sensitivity of the bond between the metal foil and the printed circuit board, you should make every possible effort to isolate malfunctions to the correct single part when troubleshooting. This procedure prevents unnecessary removal of a part and possible damage to the printed circuit board. Another problem is the difficulty of attaching thermal shunts between the solder connection and the body of the part. Thus, the main caution for you to observe in removing flush-mounted parts is not to overheat the soldered joints.

A lead-mounted part is generally bonded or protected by an epoxy-resin compound or an encapsulant material. Remove it to reach the soldered connections. Be careful when chipping away the protective coating so that you do not cut or gouge the metal-foil wiring pattern. If a part lead is bent over, straighten it as you perform the desoldering operation. However, applying too much pressure against the board when prying up the lead can seriously damage the printed circuit.

If leads on component parts are to be connected directly to the terminal, clean and tin these leads as you do wire leads. Before tinning, place a terminal shunt between the part and the tinning operation to protect the part from heat damage.

In addition to cleaning and tinning, cut the part leads to the required length and form them before soldering. Bend the part leads to provide an appropriate mounting form and slack for stress relief. Typical stress relief bends in part leads are shown in figure 5-16. Stress relief bends are gradual, with the maximum acceptable bend having a radius which is no less than twice the diameter of the lead. Start the lead bend so that it is at least 1/16 inch from the part body.

CAUTION: To prevent part damage when bending leads, support the lead between the part body and the bend, as shown in figure 5-17. Use gloves to avoid touching cleaned leads with your bare hands during the bending operation.

When soldering component parts (resistors, semiconductors, capacitors, and inductors) into electronic circuits, use thermal shunts (heat sinks). Remember, thermal shunts are devices used to protect heat-sensitive component parts from heat damage during soldering. Connect the thermal shunt between the heat-sensitive part and the connection that is to be soldered. The thermal shunt design permits rapid application and removal with minimum interference with the soldering procedure. This device provides rapid heat removal from the area being soldered.

A thermal shunt is held in place by any suitable means. Some examples of thermal shunts are shown in figure 5-18. You may want to use this type of friction (spring tension) device, which prevents damage to the surface. This type of thermal shunt protects the insulation of the wire, as well as the part being soldered.

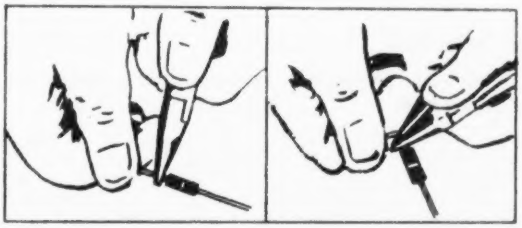


Figure 5–17. Lead bending.

Transistors are generally soldered in a circuit, particularly in printed circuits, due to their high degree of reliability. Don't remove a transistor by desoldering unless absolutely necessary. In the removal process, not only the transistor is subjected unnecessarily to heating which can cause extensive damage, but also other parts are subjected to heat damage, particularly in the case of a printed circuit board. Desolder the transistor from the equipment for testing only when detailed troubleshooting procedures indicate the transistor is faulty. In printed circuit assemblies with transistor sockets, simply remove the transistor from the socket. If you must desolder the transistor, be extremely careful. Use a thermal shunt to prevent damage to the transistor by the heat from the soldering iron. As an aid in determining when the temperature limit has been reached, place a small piece of beeswax between the semiconductor and the thermal shunt. When the wax melts, remove the source of heat immediately.

The process of removing solder from a soldered connection is as important as the soldering operation. Desoldering is required in the performance of some troubleshooting procedures, such as replacement of faulty electronic parts and reaccomplishment of unacceptable solder connections. The general procedure used in desoldering is called wicking. Wicking is the act of transferring solder from the soldered connection to the surface of a heated wire. This is easily done by using a piece of stranded wire, or braided shielding, as a wick to absorb the molten solder from the soldered connection. Desolder a connection by wicking as follows:

*a*. Connect a thermal shunt between the heat-sensitive part and the connection to be desoldered.

*b*. Strip approximately 1 inch of insulation from the end of a piece of stranded wire.

*c*. Dip the stripped end of the stranded wire in liquid flux.

*d*. Place the end of the wick on the soldered connection and the soldering tip onto the wick. This heats both the wick and the soldered connection at the same time. Molten solder from the connection is absorbed by the wick.

*e*. Simultaneously remove the soldering tip and wick when sufficient solder has been transferred from the soldered connection.

CAUTION: Apply heat for a maximum of 5 seconds with a minimum cooling period of 30 seconds between heat applications.

After desoldering a connection for troubleshooting purposes, heat the connection and detach the lead from the terminal, using the slotted end of a soldering aid. After desoldering, clean the connection before resoldering.

**Exercises (262):**

1. How are components mounted on printed circuit boards?
2. Why are part leads bent before mounting?
3. How are thermal shunts held in place?
4. Besides a thermal shunt, what else can you use as an aid when desoldering transistors?
5. What is the general procedure used in desoldering?
6. When desoldering, what is the maximum amount of time to apply heat and what is the minimum cooling time?

**263. Cite precautions to take when soldering integrated circuits (ICs).**

**Removing and Replacing ICs.** ICs are divided into two categories—linear and digital. Linear ICs, also called analog ICs, produce outputs directly proportional to their inputs. They are used for transmitter and receiver circuits. Linear ICs are used for amplifiers (audio, video, RF, and IF), squelch circuits, mixers, oscillators, and other linear circuit functions. Most linear ICs have to be custom made because the requirements of each circuit are usually different. Digital ICs perform switching functions in logic circuits.

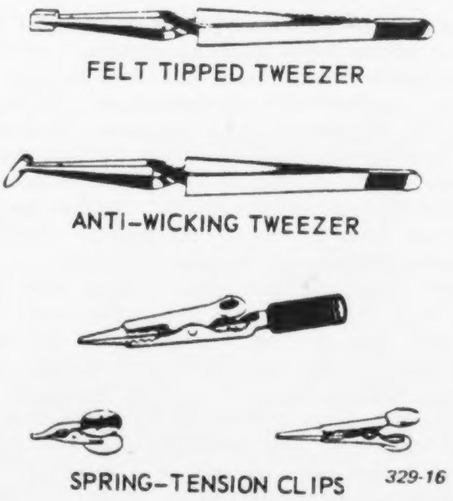


Figure 5-18. Typical and thermal short.

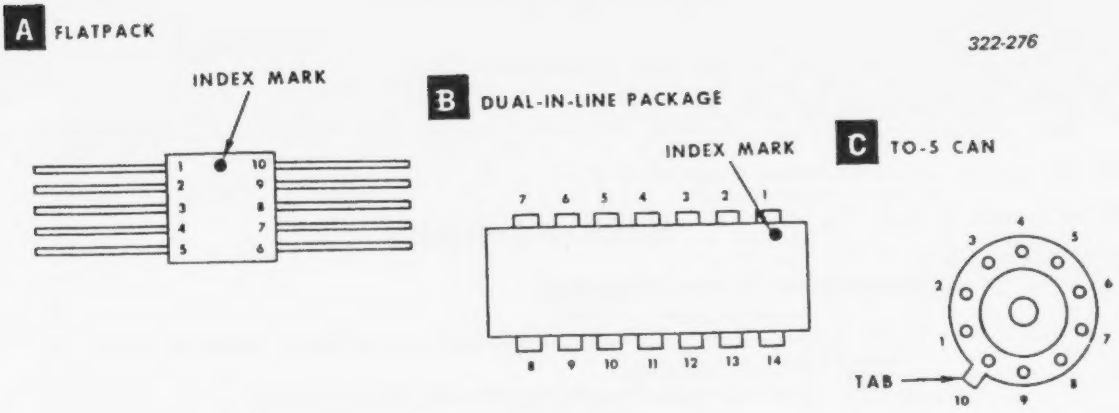


Figure 5–19. IC pin numbering.

When an IC is defective, it is thrown away. The only problem that you may face is determining which IC is bad. In some cases the equipment itself automatically pinpoints the defective IC for you. But if you don't have such sophisticated equipment, you must troubleshoot the circuit.

Troubleshooting procedures for equipment with integrated circuits are somewhat different from the procedures used for conventional circuits. With conventional circuits, you analyze the circuit, make various tests to determine the defective component, and then replace the defective component. With an IC, you can't replace the defective component even if you can identify it. Instead of circuit analysis, you have to know the overall function of the IC so that you can determine if it is doing its job.

You should perform only the authorized maintenance and repair tasks as stated in the equipment manual. Furthermore, it's very important that you use the test and repair equipment that your manual calls for.

Troubleshooting a suspected IC starts with checking its output. If the output signal indicates that something is wrong, then check to see if correct voltages are being applied to each pin. Next you should check for open circuits between the circuit board terminals and IC leads. If you still have not found the trouble, check the external components connected to the IC to determine if they are operating properly. If the external components check out, then you should replace the IC.

When replacing an IC, remember these eight important steps:

(1) Don't remove an IC until all external components are checked.

(2) Don't desolder or change any IC lead while the equipment is energized.

(3) Handle ICs with care to avoid damaging a lead.

(4) Use a thermostatically controlled soldering iron.

(5) Make sure you solder the pins to the correct terminals. Figure 5-19 shows you how the pins are numbered.

(6) Check all soldered terminals to see whether they are good or bad.

(7) After soldering in a new IC, check all IC terminal voltages.

(8) When making voltage checks on connections, be careful to avoid shorting terminals.

**Exercises (263):**

1. Cite at least five precautions to take when soldering integrated circuits.

# Bibliography

## Department of the Air Force Publications

TO 00-25-234, General Shop Practice Requirements for the Repair, Maintenance, and Test of Electronic Equipment.

TO 1-1-2, Corrosion Prevention and Control for Aerospace Equipment.

TO 32-1-101, Use and Care of Hand Tools and Measuring Tools.

# Answers for Exercises

## CHAPTER 1

**Reference:**

200 – 1. (1) c.
(2) d.
(3) f.
(4) a.
(5) f.
(6) g.
(7) b.
(8) e.
(9) b.
(10) g.
(11) a.
(12) d.

201 – 1. (1) a.
(2) e.
(3) b.
(4) c.
(5) f.
(6) a.
(7) d.
(8) e.
(9) b.
(10) f.

202 – 1. Sources of electrostatic discharge.
2. Microelectronic devices, discrete semiconductors, film resistors, resistor chips, thick and thin film devices, and piezoelectric devices.
3. When subjected to the stresses of wide temperature ranges mechanical shock, high G-forces, and landings.
4. Grounded work bench, personnel wrist strap, grounded floor mat, grounded tools, anc grounded equipment.

203 – 1. Hand syringe, camel's hair brush, lens tissue or cotton, alcohol.
2. First, blow coarse dust particles from the surface of the lens with the hand syringe. Then you use the camel's hair brush to remove smaller particles of dust. Wipe the lens gently with lens tisssue or cotton dampened with alcohol and dry it with the same material, but without alcohol.

## CHAPTER 2

204 – 1. Anaerobic bacteria.
2. Moisture, oxygen, and bacteria or fungus growths.
3. Condensation.
4. The large break allows free air circulation and ventilation.

205 – 1. Uniform etch corrosion.
2. Exfoliation corrosion.
3. Pitting corrosion.
4. Fatigue corrosion.
5. Intergranular corrosion.

206 – 1. Yes.
2. Yes.
3. (1) Carbon steel, brass, or aluminum fittings used to attach two pieces of stainless steel.
(2) Carbon steel supports used to hold stainless steel or copper lines.
(3) Carbon steel grounding clips attached to stainless steel or copper lines.
(4) Carbon steel bolts used in stainless steel fittings.
(5) Cadmium-plated steel fittings screwed into (or onto) stainless steel objects.
(6) Stainless steel wire filters mounted in aluminum frames.
(7) Fittings with a stainless steel, copper, and cadmium plating in direct contact with each other.
4. (1) Completely seal the unit.
(2) Pressurize with dry air or dry nitrogen.
(3) Spray or paint with special materials.
5. (1) Use heating and/or cooling equipment to hold the temperature to a small variation so that moisture is not drawn into component enclosures, boxes, or compartments.
(2) Use dehumidifiers to keep moisture content of the air so low that corrosion is minimized.
(3) Use filters to purify the air and reduce the problems caused by dust.
(4) Use electronic sterilization to free the air of live spores that produce fungus growths.

207 – 1. Inspect and control.
2. Repair and replacement.
3. Acetic nitrate pickle solution.
4. Areas of wear, seams, lap joints, component parts under covers, and areas where dissimilar metals meet.
5. By the formation of a dull white or gray substance on the unfinished area.
6. Remove the paint from the corroded area, wash it with an alkaline solution, rinse it clean, apply a primer, and repaint.
7. Clean the corroded area by scraping or by applying an acid solution, and wash the area. Clean all pits until the bottoms of the pits shine. Apply a primer and a protective coating.

208 – 1. A sealed, dehydrated container or shipping case.
2. A desiccant is any substance that can attract and absorb an unusual amount of moisture from air that is sealed off from the atmosphere. It is placed in containers with equipment to protect the equipment while in storage.
3. Any equipment tightly packed for extended storage is highly susceptible to anaerobic bacterial corrosion.
4. To dehydrate a container or compartment.
5. Silica gel.

209 – 1. Always depress the pressure relief valve before you open the container.
2. Moisture.
3. It must be adequately packed to protect it from possible damage by vibration and rough handling.

210 – 1. Contraction of metal parts and too much lubricant.
2. To eliminate condensation.
3. Winterize.

211 – 1. High temperatures, high humidity, abundant rainfall, and sunshine.
2. Corrosion.
3. Humid atmosphere, fungus growth, saltwater air and spray, coral dust, soil, acids, bacteria, and insects.
4. The residue from fingerprints furnishes food for fungi.
5. Insects die in the equipment and their bodies provide paths for short circuits and food for fungi.
6. Spiders spin webs in the equipment. Then dew collects on the webs and causes short circuits.
7. (1) Corrosion of contacts.
(2) Moisture in coils—fluctuation of frequency, short circuits, and burned out coils.
(3) Filter capacitors and transformers shorting and burning out.
(4) Deterioration of rubber on power cables—shorts.
(5) Rusting and corroding of exposed metal.
(6) Short circuiting of dynamotors and generators.
(7) Leakage of wires which have been formed into laced cables.
(8) Lowering of capacitor leakage resistance.
(9) Transformer failure due to breaks in windings.
(10) Relay failures due to increased resistance to movement of their cores.
8. Keep the equipment dry, clean, well ventilated, and properly lubricated, and keep film and parts in the factory wrappings until they are ready to be used.

212 – 1. High day temperatures, low night temperatures, little rainfall or moisture, and large quantities of loose, fine dust and sand blown about by wind.
2. Sand and dust particles.
3. At night if possible.
4. Clean, dry, and cool.
5. (1) Life of electronic equipment is reduced.
   (2) Dry-cell life and performance are greatly impaired.
   (3) Dust causes faulty operation of variable condensers.
6. Particles of dust mixed with lubricants act as abrasives and grinding agents. This causes loose fitting parts.
7. Endless cleaning, inspection, alertness, and hard work are required.

## CHAPTER 3

213 – 1. a. The distance between corresponding parts of two consecutive waves
   b. Any form of energy radiating from a source such as electromagnetic waves, heat, light, X-rays, and gamma waves.
   c. The number of waves that pass a fixed point in a given unit of time.
2. Color.
3. (1) b.
   (2) a.
   (3) d.
   (4) c.
   (5) e.
   (6) f.

214 – 1. The speed at which light travels.
2. The density of the medium through which the light passes.
3. Reflection is the change in direction of light after it strikes a surface.
4. Transmission is the passing of light through a medium.
5. a. Translucent.
   b. Transparent.
   c. Opaque.
6. Refraction.
7. Absorption.
8. Dispersion.
9. Light that vibrates in only one plane.

215 – 1. Refraction.
2. The amount of light allowed to pass through the lens.
3. Focal length of the lens.
4. By minimizing diffraction.

216 – 1. The rays entering the lens are bent toward the normal, and energing from the lens, the rays are bent away from the normal.
2. Positive lens.
3. Negative lens.

217 – 1. a. Chromatic aberration.
   b. Coma.
   c. Flare.
2. a. Use a smaller aperture or a negative lens in contact with a positive lens.
   b. Use a smaller aperture.
   c. Vary the radii curvature of the lens elements.
   d. Combine positive and negative lenses reducing the aperture.

218 – 1. Definition or acuteness.
2. The ability of a lens or emulsion to record fine detail distinguishably.
3. Lines per millimeter.
4. Resolving power, acuteness.

219 – 1. 2-inch focal length.
2. 3-inch focal length.

220 – 1. Lens A.
2. Lens B.
3. Lens A.
4. Lens B.
5. The same.
6. Lens B.

221 – 1. 4 seconds.
2. 16 times.

222 – 1. 1332 feet.
2. 1875 feet.

223 – 1. 65 feet: FD (142 ft.)—ND (77 ft.)
2. 15 feet: FD (59 ft.)—ND (44 ft.)

224 – 1. 1/8 second.
2. a. 1/60 second.
   b. 1/250 second.
   c. 1/500 second.

225 – 1. a. Red.
   b. Blue.
   c. No light.
   d. Green.
2. Displaces image.
3. Film sensitivity.

226 – 1. a. Type 2.
   b. Type 2.
   c. Type 1.
   d. Type 2.
   e. Type 3.

227 – 1. Neutral density filter.
2. Contrast filter.
3. Wratten Series 3 dark green filter.

228 – 1. 1/50.
2. 1/10.
3. 1/50.
4. 1/10.
5. 1/4.
6. 1/8.
7. 1/50.

229 – 1. Must be photographically inert and remain unaffected by solutions used in processing.
2. Cellulose acetate.
3. It is bulky, heavy, inflexible, and easily broken.
4. Polyethylene terephthalate.
5. A mixture of silver salts and gelatin.
6. To prevent dark streaks caused by friction, scratches, and/or abrasions prior to development.
7. A hardened gelatin.
8. To prevent light from being reflected back into the emulsion by the base, causing a halo effect.

230 – 1. The paper must withstand alkaline and acid solutions and be chemically pure to prevent chemical reaction in processing.
2. Light weight.
3. Double weight.
4. Single weight.
5. Barium sulfate and gelatin.
6. If the paper is to be folded or creased.
7. Silver chloride, silver chlorobromide, and silver bromide.
8. Properties of light sensitivity and contrast.

231 – 1. The developer converts the light-affected silver halides to black metallic silver to form a image on the film.
2. Chemical concentration, variations in temperature, and variations in development time.
3. The reducing agent develops the silver halides to a metallic silver.
4. The preservative prevents excessive oxidation of the developer to prolong the life and prevent the formation of colored oxidation products, which cause stain.
5. Oxidation tendency, concentration, temperature, keeping property, the way it is used, and the alkalinity of the solution.

6. To make the developer alkaline. It speeds up the swelling of the gelatin in the emulsion and absorbs the halogen elements freed from the silver to prevent harmful effects on the solution.
7. The restrainer prevents the developer from acting too rapidly and developing unexposed silver halides near the surface. It prolongs developing time and minimizes chemical fog.

232 – 1. The stop bath is to remove the developer from the negative to aid in the prevention of stains.
2. a. To remove the excess developer from the film or paper to prevent contamination of the fixing bath.
   b. To instantly neutralize the alkalinity of the developer to stop further development before using the fixing bath.
   c. When the control of solution temperatures cannot be maintained.

233 – 1. The fixing agent is used to convert the silver salts remaining in the emulsion to soluble compounds.
2. The preservative is used to prevent oxidation of the developer carryover.
3. The neutralizer is used to stop development and prevent stains.
4. The hardener is used to prevent scratches, frills, or undesirable effects from the soft, wet emulsion.
5. To absorb most of the developer before sludge can form, thus extending the life of the bath.

## CHAPTER 4

234 – 1. Make certain to use blocking or other supports when lifting a vehicle with jacks.
2. Goggles.
3. To reduce damage to toes from falling objects.
4. Rotating machinery.
5. You should wipe the tools dry because a rapid and extreme change in temperature can cause moisture condensation that may cause the surface to rust or corrode.
6. The cutting edge should be wrapped with a clean rag to keep from breaking the cutting edge and to protect you from accidental injury.

235 – 1. For bending and beveling metal.
2. For straightening and bumping metal.
3. To drive and remove nails.
4. Head weight.
5. For peening riveting.
6. Welder's hammer.
7. Blacksmith's or sledge hammer.
8. The mallet is so designed that you can apply force to some other material without damaging it.
9. Keep the handle and face clean and never use a mallet or hammer with a loose head.
10. To drive wooden-handled chisels, wooden dowels, or small stakes, and for smoothing out dents in sheet metal.
11. Rawhide mallet.

236 – 1. Heavy-duty work.
2. Size 1.
3. Small screws.
4. Wide enough to go across the entire length of the screw slot.
5. To turn screws.

237 – 1. A spanner wrench.
2. A setscrew wrench.
3. A socket wrench.
4. Adjustable pipe wrench.
5. Torque wrench.

238 – 1. Parallel-jaw, flat, or roundnose pliers.
2. Slip-joint combination pliers.
3. Diagonal cutting pliers.

239 – 1. For holding or handling small parts.
2. a. Don't use as pliers.
   b. Make sure the jaw-holding surfaces are parallel.
   c. Store so they are not damaged by rust, corrosion, or bending.

240 – 1. A coarse file.
2. (1) Kind of material to be filed.
   (2) Shape of cut to be made.
   (3) The amount of material to be removed.
   (4) The type of finish desired.
3. To prevent damage to work being shaped.
4. Never use lubricant on a file.
5. To prevent rust.

241 – 1. We hope you answered that no one precaution is the most important. We want you to think about each of the precautions given. If you fail to wear goggles and protect your fellow workers, someone could be blinded or seriously injured. If you don't hold the chisel properly, the work will not be done as desired, and you may hurt your hand. If you don't use the hammer properly, you may hit your hand with it. Oil on your hand, the chisel, or hammer may cause an injury to you or someone else. When the mushroomed head of a chisel is struck, a piece of metal may break off and strike your hand with enough force to penetrate the skin.

242 – 1. You should use a blade with fine teeth for cutting tool steel because it is hard metal.
2. The saw moves in an up-and-down motion with the cutting action taking place on the downward stroke.

243 – 1. When working on electronic equipment, tuning RF circuits, and IF circuits.
2. Insulated tool.
3. Wipe with a lint-free cloth dampened with a suitable cleaning solvent.
4. Nonmagnetic tool.

244 – 1. To remove and insert taper pins.
2. Crimping tool.

245 – 1. For retrieving small articles from places that cannot be reached by hand and to start nuts or bolts in areas that are difficult to reach.
2. The fingers are thin sheet metal and can be easily damaged.
3. To aid in making detailed inspections where the eye cannot directly see the area.

246 – 1. To remove a straight pin or taper pin after it has been loosened.
2. To make small indentions on layout lines, timing marks, etc.
3. For aligning holes in two pieces to simplify inserting bolts, rivets, etc.
4. The only maintenance required is the refinishing of the tip and head.

247 – 1. To remove screws, bolts, studs, etc., that have been broken off inside a hole.
2. Drill a hole in the center of the screw, insert the extractor, and turn the extractor counterclockwise using a tap wrench.
3. Clockwise.

248 – 1. It should not exceed the chuck size.
2. By direct-contact backing of the material being drilled with another piece of scrap metal.

249 – 1. Bench or floor type.
2. Lubricants or coolants.
3. To protect your eyes from hot burrs of metal.

250 – 1. (1) b.
   (2) c.
   (3) e.
   (4) d.
   (5) a.
   (6) f.

251 – 1. They are used for reshaping and sharpening small handtools.
2. By visual inspection and tapping it lightly with a mallet.
3. Ensure that it is wiped free of oil and grease.
4. Eye protection.

252 – 1. English and metric systems.
2. A folding rule.

253 – 1. To show if the work is square; also used with a thickness gauge.
2. To measure precision angles.

254 – 1. (1) b.
(2) a and d.
(3) c.

255 – 1. a. = 0.400
b. = 0.025
c. = 0.014
T = 0.439

256 – 1. Thickness (feeler) gauge.
2. Screw pitch gauge.
3. Twist drill or drill rod gauge.
4. Wire gauge.

## CHAPTER 5

257 – 1. To form a continuous and permanent metallic connection having a constant electrical value.
2. Soldering is the process of joining two (or more) metals together by the application of heat and a low melting point alloy which flows between and around metals being joined and, upon cooling, solidifies and bonds the metals together.
3. a. Protect eyes and skin with clothing and protective devices.
   b. Never rest a hot soldering iron on a wood bench or chair.
   c. Never flip excess solder from the tip of the soldering iron.
   d. Never wear rings or watches while soldering.
   e. Always disconnect electronic equipment from the power source.
   f. Always ground soldering irons or guns to eliminate electric shock.

258 – 1. Copper is a good conductor of heat.
2. Tinning the tip.
3. (1) Clean, shape, and smooth the cold tip; (2) heat the soldering iron; (3) rub the tip on a surface where both solder and flux can be applied simultaneously while the tip heats; (4) continue the procedure until the iron gets hot enough to melt the solder and coats the tip; (5) wipe excess solder from the tip with a clean, damp sponge or cloth.
4. A heat sink.

259 – 1. Teflon, PVC, and silicone-rubber insulations should be stripped in a well-ventilated area.
2. To strip the insulation from wire in one operation.
3. The teeth will cut into the wire and weaken the wire.
4. By encasing the tips with covers of copper tubing.
5. Brush and knife.

260 – 1. An approved wire stripper.
2. In the direction that maintains the original form and prevents separation of the individual strands.
3. To avoid damaging the shielding or the insulated wire.
4. It must be supported so that there is no movement.
5. The wire contacts the terminal, and its contour is visible under a thin solder coating. The solder, forming a concave fillet on each side of the wire, blends into the terminal surface in a smooth, continuous feathered edge.

261 – 1. A pencil-style typewriter eraser.
2. 180° and 360°.
3. One and 1½.

262 – 1. Lead-mounted and flush-mounted.
2. To provide a stress relief.
3. By any suitable means.
4. Beeswax.
5. Wicking.
6. 5 seconds and 30 seconds.

263 – 1. (1) Don't remove an IC until all external components are checked; (2) don't desolder or change any IC lead while the equipment is energized; (3) handle IC's with care to avoid damaging a lead; (4) use a thermostatically controlled soldering iron; (5) make sure you solder the pins to the correct terminal; (6) check all soldering terminals to see whether they are good or bad; (7) after soldering in a new IC, check all IC terminal voltages; (8) when making voltage checks on connections, be careful to avoid shorting terminals.

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